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The Power Gain of Multi-Tiered V.H.F. Transmitting Aerials

by

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BRITISH BROADCASTING CORPORATION

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FOREWORD

This is one of a series of Engineering Monographs published by the British Broadcasting Corporation. About six are produced every year, each dealing with a technical subject within the field of television and sound broadcasting. Each Monograph describes work that has been done by the Engineering Division of the BBC and includes, where appropriate, a survey of earlier work on the same subject. From time to time the series may include selected reprints of articles by BBC authors that have appeared in technical journals. Papers dealing with general engineering developments in broadcasting may also be included occasionally.

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THE POWER GAIN OF MULTI-TIERED V.H.F. TRANSMITTING AERIALS

SUMMARY

Transmitting aerials for v.h.f. broadcasting usually consist of a number of similar groups or tiers of radiating element, spaced at intervals along a supporting mast. The power gain of such an arrangement depends on the number of tiers on the spacing between them, and also on the vertical radiation pattern of each individual tier. A method of calculating the gain is described in this monograph. Results computed for a comprehensive range of variables are presented in the form of tables.

1. Introduction

V.H.F. broadcasting aerials are usually designed so as to concentrate as much of the radiated power as possible into the horizontal plane. This is achieved by mounting co-phased groups or tiers of radiating elements along a length of the supporting mast. The effective radiated power (e.r.p.) is then greater than the actual radiated power, the ratio of the two powers being known as the power gain. The latter is roughly proportional to the length of mast occupied by the aerial, but it also depends on the number and type of the individual tiers and on the spacing between them. It is a factor of considerable importance in aerial design.

In a definition of power gain a comparison must be made with a standard or reference aerial. This may be an isotropic source, a short doublet, or a half-wave ($\lambda/2$) dipole; the latter is commonly used because it is the simplest form of practical aerial. Power gain is then defined as the ratio of the power which must be fed to the reference aerial to that fed to the aerial under consideration in order to produce identical field strengths at a distant point.* It is also equal to the square of the ratio of the field strengths which the aerials would produce at a distant point if they radiated equal powers. The gain may be expressed either as a power ratio or in decibels, and the type of reference aerial must always be stated.

The tiers of a v.h.f. transmitting aerial are usually equally spaced and fed with equal co-phased currents. The design of the individual tiers is governed by polarization and horizontal radiation pattern (h.r.p.) requirements, and by the shape and dimensions of the mast structure; vertical directivity is usually a secondary consideration. The power gain of the aerial depends mainly on the number of tiers and on the spacing between them, and for any given number there is an optimum spacing which results in the maximum gain. Both the gain and the optimum spacing depend also on the vertical radiation pattern (v.r.p.) of the individual tiers but to an ever-decreasing extent as the number of tiers is increased.

In the past, gains of multi-tiered v.h.f. aerials have often been calculated by an integration based on their v.r.p.s. Optimum dimensions were determined by repeating the calculation for different inter-tier spacings until the maximum gain was found. This was a slow process and it had therefore to be confined to specific cases. The development of the digital computer has now made it possible to produce comprehensive tables of power gains covering a wide range of spacings, types of radiating elements, and numbers of tiers. These tables are reproduced in this monograph.

The monograph also contains tables of the relative mutual resistance between tiers as a function of the distance between them. These may be used to calculate the gains of aerials whose spacings or numbers of tiers lie outside the range of values covered by the gain tables. They may also be used to calculate the gains of aerials with unequal inter-tier spacings, or with tiers fed with unequal currents.

* The distant point is usually in the direction of maximum radiation, but not necessarily so; the gain of an aerial may be specified in any direction. When no direction is stated, the figure quoted may be assumed to apply to the direction of maximum radiation. In this monograph we are concerned with the gain normal to the axis of the array.

2. Theoretical Considerations

There are two ways in which the gain of an aerial can be calculated. In one method, the three-dimensional radiation pattern is determined and the power flowing through a sphere containing the aerial is found by integration. In the other method the power is calculated directly from the relative mutual resistances between the elements comprising the aerial. As a combination of both methods was used for the calculations described in this monograph a brief outline of them is given below.

2.1 *Gain by Pattern Integration*

Fig. 1 represents an aerial situated at the centre of a sphere. If the field strength at any point on the surface of the sphere is E, the power radiated through an element δs of the surface area is $kE^2\delta s$, k being a constant. The total power radiated is obtained by performing an integration over the surface of the sphere.

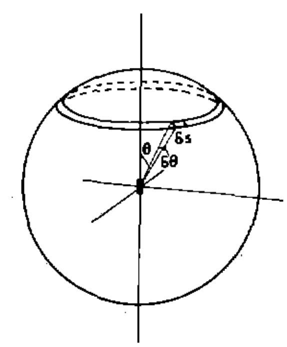

Fig. 1 — Calculation of aerial gain by radiation pattern integration

Suppose that the maximum field radiated by the aerial is unity and that we use an isotropic source radiating unit field as our reference. The power radiated by the latter is $4\pi k$ and the gain of the aerial relative to an isotropic source is therefore

$$G_o=\frac{4\pi}{\int_s E^2 ds} \tag{1}$$

Its gain relative to a $\lambda/2$ dipole is

$$G=\frac{4\pi}{1\cdot 64092\int_s E^2 ds} \tag{2}$$

since the gain of a $\lambda/2$ dipole relative to an isotropic source is $1\cdot 64092$.*

The integration is greatly simplified if the aerial has symmetry about an axis. Suppose that this is the vertical axis of Fig. 1; then the field strength is constant in all directions which make an angle θ to the axis. Since the area of the zone which subtends an angle θ is proportional to $\sin\theta\,\delta\theta$, the power radiated through the zone is given by

$$\delta W=kE^2\sin\theta\,\delta\theta \tag{3}$$

The gain relative to a $\lambda/2$ dipole is therefore

$$G=\frac{4\pi}{1\cdot 64092\int_s^{\pi} E^2 \sin\theta\, d\theta} \tag{4}$$

2.2 *Gain from Mutual Resistance*

The gain of an aerial may also be calculated from the self- and mutual resistances of its elements. For example, let us consider a simple aerial consisting of two elements. It is shown in Appendix I that the total power radiated, and hence the gain, depends only on the self- and mutual resistances of the elements and is independent of their reactances. This result is true for any number of similar or dissimilar elements having any current distribution.

If the two elements are identical and carry equal currents, the expression for the radiated power is

$$W=2I^2(R_S+R_M)$$

where R_S and R_M are the self- and mutual resistances of the elements and I is the current flowing in them. Now a single element would have to carry a current of $2I$ and radiate a power of $4I^2R_S$ in order to produce the same field strength in the direction of maximum radiation. Thus the gain of the array relative to a single element is

$$G_R=\frac{4I^2R_S}{2I^2(R_S+R_M)}=\frac{2}{1+R_M/R_S} \tag{5}$$

The quantity R_M/R_S is known as the relative mutual resistance and is denoted in this report by $R(x)$. The envelope of the mutual resistance decreases as the spacing between the elements increases and the gain therefore tends to a limiting value of 2 (3 dB). This is illustrated by Fig. 2, which shows how the relative mutual resistance and gain of two parallel $\lambda/2$ dipoles varies with their separation.

* The gain of a $\lambda/2$ dipole relative to an isotropic source is equal to $4/[\gamma+\log 2\pi - Ci(2\pi)]$, where $\gamma=0\cdot 57722$ (Euler's constant) and $Ci(z)$ denotes the cosine integral.

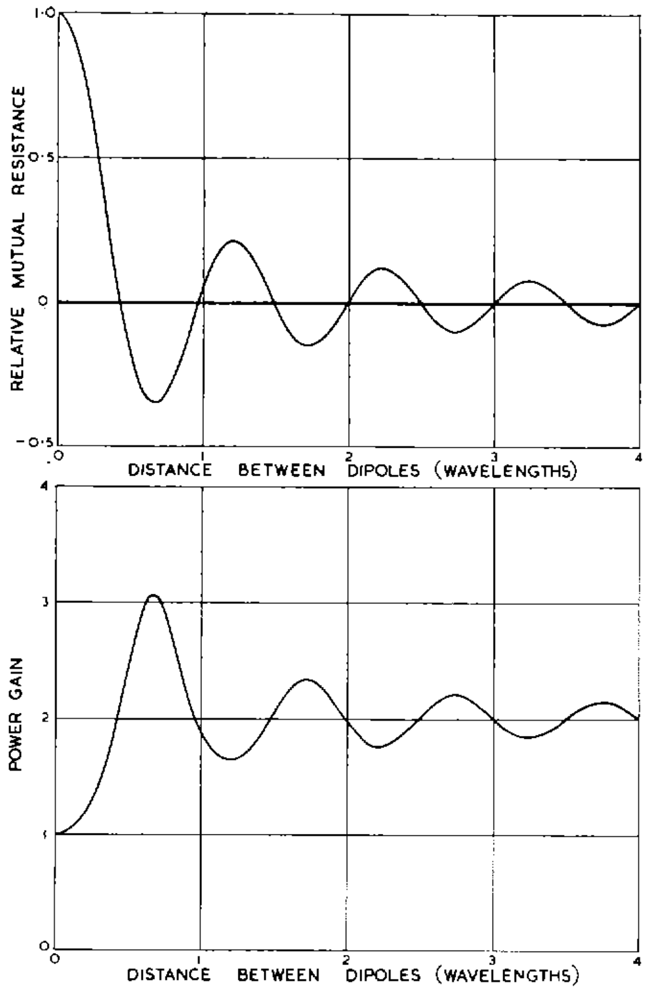

Fig. 2 — The relative mutual resistance and gain of two parallel $\lambda/2$ dipoles

2.3 *The Mutual Resistance Between Two Identical Sources*

The first step in calculating the gain of a multi-tiered array is to determine the relative mutual resistance between tiers as a function of their separation.

Fig. 3 represents two identical sources with cylindrical symmetry about the axis AB. If each individual source carries a current I and has a radiation pattern whose

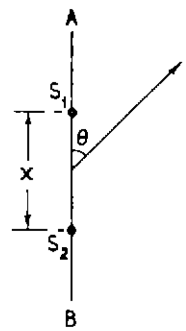

Fig. 3 — Two identical sources

modulus is denoted by $f(\theta)$, the power which it would radiate in the absence of the other is

$$I^2R_s=k\int_0^\pi \{f(\theta)\}^2 \sin\theta\, d\theta \tag{6}$$

where R_s is its self-resistance and k is a constant.

The radiation pattern of two sources driven by equal co-phased currents is

$$E=2f(\theta)\cos(\tfrac{1}{2}\beta x\cos\theta)$$

where x is the distance between them and $\beta=2\pi/\lambda$. The power which they radiate is therefore

$$\begin{aligned} W&=k\int_0^\pi 4\{f(\theta)\}^2\cos^2(\tfrac{1}{2}\beta x\cos\theta)\sin\theta\, d\theta \\ &=2k\int_0^\pi\{f(\theta)\}^2\sin\theta\, d\theta+2k\int_0^\pi\{f(\theta)\}^2\cos(\beta x\cos\theta)\sin\theta\, d\theta \\ &=2I^2R_s+2k\int_0^\pi\{f(\theta)\}^2\cos(\beta x\cos\theta)\sin\theta\, d\theta \end{aligned} \tag{7}$$

Now the total power radiated is also equal to

$$W=2I^2(R_s+R_M) \tag{8}$$

where R_M is the mutual resistance between the sources. Combining Equations (7) and (8) we therefore have

$$I^2R_M=k\int_0^\pi\{f(\theta)\}^2\cos(\beta x\cos\theta)\sin\theta\, d\theta \tag{9}$$

An expression for the relative mutual resistance $R(x)$ may now be derived from Equations (6) and (9),

$$R(x)=\frac{R_M}{R_s}=\frac{\int_0^\pi\{f(\theta)\}^2\cos(\beta x\cos\theta)\sin\theta\, d\theta}{\int_0^\pi\{f(\theta)\}^2\sin\theta\, d\theta} \tag{10}$$

These integrals can be solved analytically for a few special cases such as isotropic sources $[f(\theta)=1]$ and collinear doublets $[f(\theta)=\sin\theta]$ and it is possible to derive a solution for collinear $\lambda/2$ dipoles in terms of cosine integrals. But in general the integrals cannot be evaluated in closed form. This difficulty may be overcome by representing the v.r.p. of each tier by an empirical formula for which a solution can be obtained. This formula would contain parameters which may be chosen to give the closest possible approximation to the actual radiation pattern. The relative mutual resistance $R(x)$ may then be calculated, and the array gain determined.

One such empirical formula which may be used to represent the v.r.p. of a single tier is

$$f(\theta)=[1+P\cos^2\theta+Q\cos^4\theta]^{\frac{1}{2}} \tag{11}$$

where P and Q are the parameters which define the shape of the pattern. Since $f(\theta)$ represents the modulus of the v.r.p. and is therefore a real number, P and Q are subject to the restriction $(P+Q)\geqslant -1$. Values of these parameters between -4 and $+4$ cover the majority of the v.r.p.s encountered in practice; the choice of them is discussed in greater detail in Section 3.

Since the expression for $f(\theta)$ is symmetrical about $\theta=\pi/2$, the limits of integration for Equation (10) may be restricted to the range $0<\theta<\pi/2$. Equations (10) and (11) may also be rewritten in terms of a new variable $u=\cos\theta$. The empirical formula for the v.r.p. of a single tier then becomes

$$[1+Pu^2+Qu^4]^{\frac{1}{2}}$$

and the relative mutual resistance is given by

$$R(x)=\frac{\int_0^1(1+Pu^2+Qu^4)\cos\beta xu\, du}{\int_0^1(1+Pu^2+Qu^4)du} \tag{12}$$

The integrals may now be evaluated, leading to the result

$$R(x)=\frac{1}{K}\{[A_1(\beta x)^{-1}+A_3(\beta x)^{-3}+A_5(\beta x)^{-5}]\sin\beta x + [A_2(\beta x)^{-2}+A_4(\beta x)^{-4}]\cos\beta x\} \tag{13}$$

where

$$\begin{aligned} A_1&=1+P+Q & A_4&=-24Q \\ A_2&=2(P+2Q) & A_5&=24Q \\ A_3&=-2(P+6Q) & K&=1+P/3+Q/5 \end{aligned}$$

This expression was used for the relative mutual resistance computations described in this monograph.

2.4 *The Gain of a Single Tier*

The gain of a multi-tiered array must be related to a known standard such as an isotropic source or a $\lambda/2$ dipole. In order to do this it is necessary to calculate the gain of a single tier.

The gain of a tier defined by the parameters P and Q, relative to an isotropic source, is

$$\begin{aligned} G_0&=\frac{\int_0^\pi\sin\theta\, d\theta}{\int_0^\pi\{f(\theta)\}^2\sin\theta\, d\theta}=\frac{1}{\int_0^1(1+Pu^2+Qu^4)du} \\ &=\frac{1}{1+P/3+Q/5}=\frac{1}{K} \end{aligned} \tag{14}$$

The gain of a $\lambda/2$ dipole relative to an isotropic source is $1\cdot64092$. Thus the gain of a single tier relative to a $\lambda/2$ dipole is $1/1\cdot64092K$. Note that this is the gain in the plane defined by $\theta=\pi/2$ and is not necessarily the maximum gain; for example, the power gain of a doublet turnstile in a direction along its axis is twice that in a direction normal to the axis.

2.5 *The Gain of a Multi-tiered Array*

The gain of a linear array of identical sources can be determined from self and mutual resistances. Let us consider the array of n identical sources shown in Fig. 4.

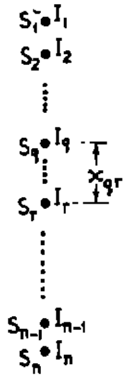

Fig. 4 — An array of n identical sources

It is shown in Appendix I that the total power radiated by an array of n sources is

$$W=\sum_{q=1}^{n}\sum_{r=1}^{n} R_{qr}I_qI_r^* \tag{15}$$

where I_q is the current in the qth source and I_r^* is the complex conjugate of the current in the rth source. R_{qr} is the mutual resistance between the qth and rth sources.

If the sources are identical we may write $R_{qr}=R_sR(x_{qr})$, where R_s is the self-resistance of one source and $R(x_{qr})$ is the relative mutual resistance between the two sources. The power radiated is then

$$W=R_s\sum_{q=1}^{n}\sum_{r=1}^{n} R(x_{qr})I_qI_r^* \tag{16}$$

Now the field at a distant point, in the direction normal to the axis of the array, is proportional to the sum of the radiating currents. A single source carrying the same total current would produce the same field strength at the distant point and would radiate a power

$$W_0=R_s\left|\sum_{r=1}^{n} I_r\right|^2$$

The gain of the array relative to a single source is therefore

$$G_R=\frac{W_0}{W}=\frac{\left|\sum_{r=1}^{n} I_r\right|^2}{\sum_{q=1}^{n}\sum_{r=1}^{n} R(x_{qr})I_qI_r^*} \tag{17}$$

The number of terms in the double summation can be reduced by grouping identical terms in pairs, giving

$$G_R=\frac{\left|\sum_{r=1}^{n} I_r\right|^2}{\sum_{r=1}^{n}|I_r|^2+2\sum_{r=1}^{n}\sum_{q=1}^{r-1} R(x_{qr})I_qI_r^*} \tag{18}$$

If the sources carry equal currents $I=I_q=I_r$ and $I_qI_r^*=|I|^2$, the gain is then

$$G_R=\frac{n^2}{n+2\sum_{r=1}^{n}\sum_{q=1}^{r-1} R(x_{qr})} \tag{19}$$

If the tiers are also equally spaced, the expression reduces to

$$G_R=\frac{n^2}{n+2\sum_{r=1}^{n-1}(n-r)R(rx)} \tag{20}$$

where x is the spacing between tiers and $R(rx)$ denotes the relative mutual resistance between two tiers separated by a distance rx.

It is more usual to refer the gain to that of a $\lambda/2$ dipole. Since the gain of a single tier relative to a $\lambda/2$ dipole is $1/1\cdot64092K$, the gain of the array referred to this standard is therefore

$$G=\frac{n^2}{1\cdot64092K\left[n+2\sum_{r=1}^{n-1}(n-r)R(rx)\right]} \tag{21}$$

It is often more convenient to consider the gain per tier of the array, since this is a quantity which varies slowly with the number of tiers and which tends to a limiting value as the number of tiers increases. The gain per tier relative to a $\lambda/2$ dipole is

$$\frac{G}{n}=\frac{1}{1\cdot64092K\left[1+\frac{2}{n}\sum_{r=1}^{n-1}(n-r)R(rx)\right]} \tag{22}$$

2.6 *The Gain of Arrays Having a Large Number of Tiers*

The limiting value of the gain per tier of arrays having large numbers of tiers is of considerable interest because it is closely approached by arrays having more than eight tiers.

In the first place we will consider, in a qualitative manner, how the gain of a finite number of identical tiers varies with the inter-tier spacing. For this purpose it is better to consider the radiation pattern rather than the mutual resistance.

If we assume for the sake of simplicity that each tier is an isotropic source, the v.r.p. of n tiers is given by

$$\frac{\sin(\frac{1}{2}n\beta x\cos\theta)}{n\sin(\frac{1}{2}\beta x\cos\theta)}$$

where x is the inter-tier spacing. Fig. 5 shows the modulus of this plotted as a function of $\cos\theta$ for $n=16$ and $x=0\cdot8\,\lambda$. In order to demonstrate the way in which the pattern changes as x varies, the curve has been extended outside the range $-1\leqslant\cos\theta\leqslant1$; the real radiation pattern of the array is, of course, represented by the portion of the curve lying between the limits $\cos\theta=\pm1$.

If x is increased the curve will contract horizontally and more of it will come within the range $-1\leqslant\cos\theta\leqslant1$. Suppose that x increases steadily. At first the main effect will be a reduction in the radiated power, and hence an increase in the gain, as the lobes near $\cos\theta=0$ contract. As x approaches one wavelength, reinforcement along the axis becomes possible and two new major lobes begin to enter the significant region. There will therefore be a rapid increase in the radiated power and the gain will fall sharply. However, when the new major lobes, and the minor lobes surrounding them, have almost entirely entered the significant region a further slow reduction in the radiated power

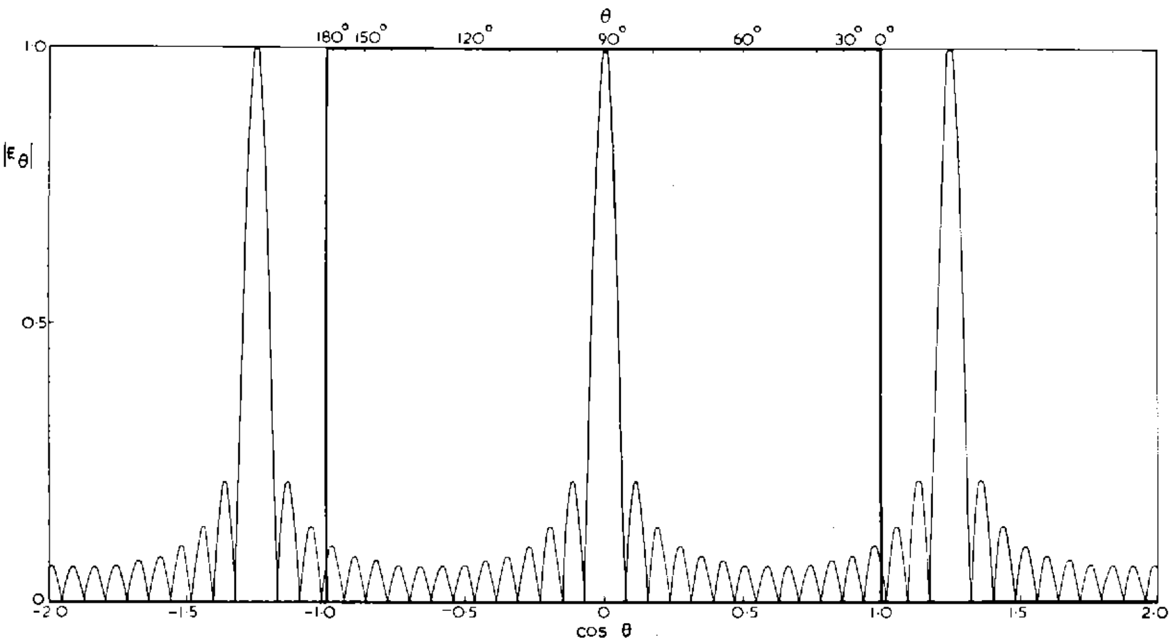

Fig. 5 — The v.r.p. of 16 isotropic sources spaced 0·8λ

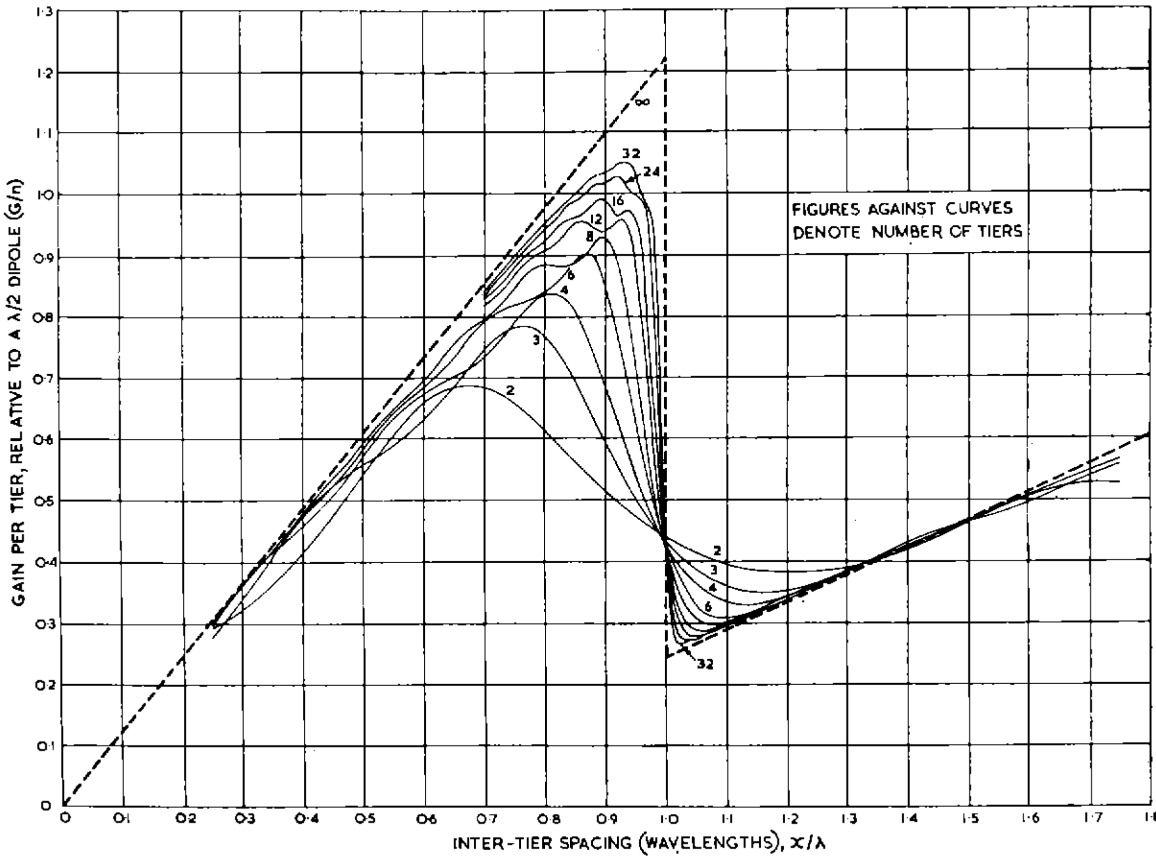

Fig. 6 — The gain per tier of arrays of doublet turnstiles ($P=1$, $Q=0$)

will commence. This process will be repeated whenever x reaches a multiple of a wavelength, since two additional major lobes are then formed.

If the array has n tiers there will be $n-2$ minor lobes between the major lobes. When n is large most of the minor lobes are insignificant and only those adjacent to the major lobes contribute appreciably to the radiated power (about 90 per cent of the power is concentrated in the major lobes). As the number of tiers is increased the major lobes become narrower and their entry into the significant region is delayed until the inter-tier spacing more closely approaches a multiple of one wavelength. The gain therefore falls more sharply when this point is reached; this is well illustrated by Fig. 6, which shows computed values of the gain per tier for arrays having different numbers of tiers. In the limit (an infinite number of tiers) the gain per tier curve becomes discontinuous whenever the inter-tier spacing reaches a multiple of one wavelength. In deriving the shape of this curve, inter-tier spacings less than and greater than one wavelength will be considered separately.

2.6.1 *The Gain of Infinite Arrays with Spacings Less than One Wavelength*

In this case the gain may be calculated directly from the radiation pattern by the method described in Section 2.1. The normalized v.r.p. of an array of n identical sources whose individual v.r.p.s are $f(\theta)$ is given by

$$E=\frac{\sin(\frac{1}{2}n\beta x\cos\theta)}{n\sin(\frac{1}{2}\beta x\cos\theta)}f(\theta) \tag{23}$$

where x is the distance between adjacent sources. The power radiated by the array is therefore proportional to

$$W=\int_0^{\pi}\frac{\sin^2(\frac{1}{2}n\beta x\cos\theta)}{n^2\sin^2(\frac{1}{2}\beta x\cos\theta)}[f(\theta)]^2\sin\theta\, d\theta \tag{24}$$

Making the substitution $u=\cos\theta$ and writing $f(u)=[f(\theta)]^2$ we have

$$W=\int_{-1}^{1}\frac{\sin^2\frac{1}{2}n\beta xu}{n^2\sin^2\frac{1}{2}\beta xu}f(u)du$$

When $n\beta x$ is large the radiation is confined to a small range of angles near the plane perpendicular to the line of the array. In this region we may write $f(u)=1$ and $\sin\frac{1}{2}\beta xu=\frac{1}{2}\beta xu$ without error. Outside the region the use of these approximations introduces negligible error because the contributions to W are very small. The integral may therefore be simplified to

$$W=\int_{-1}^{1}\frac{\sin^2\frac{1}{2}n\beta xu}{(\frac{1}{2}n\beta xu)^2}\,du \tag{25}$$

Making the substitution $y=\frac{1}{2}n\beta xu$ we have

$$W=\frac{2}{n\beta x}\int_{-\frac{1}{2}n\beta x}^{\frac{1}{2}n\beta x}\frac{\sin^2 y}{y^2}\,dy \tag{26}$$

The limiting value of W, as n tends towards infinity, is therefore $2\pi/n\beta x$, since

$$\int_{-\infty}^{\infty}\frac{\sin^2 y}{y^2}\,dy=\pi$$

Now the power radiated by an isotropic source producing the same field strength at a distant point is

$$\int_0^{\pi}\sin\theta\, d\theta=2$$

Thus the gain of the array relative to an isotropic source is $n\beta x/\pi$ and the gain per tier relative to a $\lambda/2$ dipole is $\beta x/1{\cdot}64092\pi$. Since $\beta=2\pi/\lambda$, this limiting value is also equal to $1{\cdot}21883x/\lambda$. This result is independent of the radiation patterns of the individual sources.

2.6.2 *The Gain of Infinite Arrays with Spacings Greater than One Wavelength*

When the spacing exceeds a wavelength, additional major lobes, whose relative amplitudes are governed by the radiation pattern of the individual sources, are formed and the gain is therefore no longer independent of the source pattern.

Before deriving an expression for the gain an important result must be proved. This states that the powers radiated in all the major lobes of an infinite linear array of isotropic sources are equal.

The radiation pattern of an array of n isotropic sources is

$$E=\frac{\sin n\psi}{n\sin\psi}$$

where $\psi=\frac{1}{2}\beta x\cos\theta$ and x is the spacing between them. The pattern is periodic in ψ, with identical maxima at values of ψ given by $\psi=0, \pi, 2\pi \ldots$ When n is large the distant field strength is significant only in a small range of angles, $\delta\psi$, near the maximum. Now the power radiated in this range depends on the area of the zone subtending a corresponding angle $\delta\theta$ on the sphere enclosing the array, and this is itself proportional to $\sin\theta\,\delta\theta$. Since $d\psi/d\theta=-\frac{1}{2}\beta x\sin\theta$, this area is proportional to $-[2/\beta x]\delta\psi$, which is independent of θ. Thus the powers radiated near each of the maxima are equal and all the major lobes contain equal powers.

Before considering the general case, it is of interest to see how the gain of an infinite array of isotropic sources varies as the spacing increases. It has already been shown that for spacings less than one wavelength the gain per source, relative to a $\lambda/2$ dipole, is $1{\cdot}21883x/\lambda$. This has a limiting value, as the spacing approaches one wavelength from below, of $1{\cdot}21883$. Turning now to the case in which the spacing exceeds a wavelength, additional major lobes are formed in directions $\theta=0$ and π and since all three major lobes carry equal powers, the limiting value of the gain per source, as the spacing approaches one wavelength from above, is $1{\cdot}21883/3=0{\cdot}40628$. Thus the curve of the gain per source of an infinite array has a discontinuity at $x=\lambda$, while the curve for a finite array of isotropic sources falls sharply.

As the spacing increases beyond one wavelength the gain per source again increases linearly and is equal to $0{\cdot}40628x/\lambda$ relative to a $\lambda/2$ dipole. This may be proved by a method similar to that used for spacings of less than one wavelength. Two more major lobes are formed when

the spacing reaches two wavelengths and the gain falls to $\frac{2}{5}(1\cdot21883)$. In general, $2r+1$ major lobes are present when the spacing lies between r and $r+1$ wavelengths. Thus the gain per source of an infinite array of isotropic sources relative to a $\lambda/2$ dipole may be stated as

$$\frac{G}{n}=\frac{1}{2r+1}1\cdot21883\frac{x}{\lambda};\quad [r\lambda<x<(r+1)\lambda] \tag{27}$$

The variation of G/n as a function of x is shown in Fig. 7.

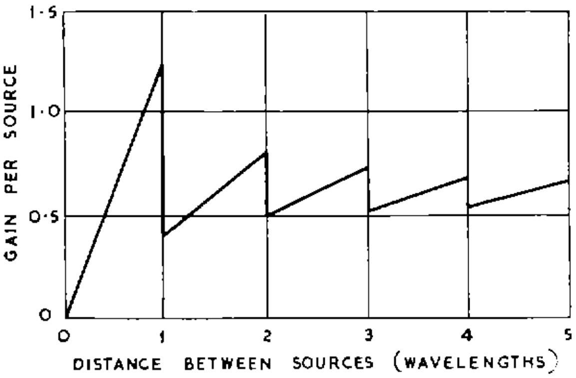

Fig. 7 — The gain per source relative to a $\lambda/2$ dipole of an infinite array of isotropic sources

In the general case in which the v.r.p. of each source is described by $f(\theta)$, the powers radiated in the major lobes are not equal but are proportional to the appropriate values of $[f(\theta)]^2$. The total power radiated (and therefore the gain) differs from that of an array of isotropic sources by a factor which depends on $f(\theta)$.

Suppose that the spacing lies between one and two wavelengths. Three major lobes are then present, at angles θ_1, $\pi/2$, and θ_2, the values of θ_1 and θ_2 being given by $\cos\theta=\pm\lambda/x$. If $f(\pi/2)=1$ the total power radiated is proportional to

$$S=1+[f(\theta_1)]^2+[f(\theta_2)]^2$$

Increasing the spacing beyond one wavelength therefore increases the power radiated by the array S times, while for a similar array of isotropic sources the corresponding increase is three times. The gain of the array relative to that of a similar array of isotropic sources is therefore $3/S$. Since the gain per tier of an array of isotropic sources in the range $\lambda<x<2\lambda$ is $1\cdot21883x/3\lambda$, the gain per tier of the array is

$$\frac{G}{n}=\frac{1\cdot21883}{S}\frac{x}{\lambda} \tag{28}$$

If the radiation pattern of the individual sources is symmetrical about $\theta=\pi/2$, $f(\theta_1)=f(\theta_2)$ and the expression for the gain may be written

$$\frac{G}{n}=\frac{1\cdot21883}{1+2[f(\theta_1)]^2}\frac{x}{\lambda} \tag{29}$$

When $x=\lambda$ the two possible values of G/n are $1\cdot21883$ and

$$\frac{1\cdot21883}{1+2[f(0)]^2}$$

where $f(0)$ is the value of $f(\theta)$ at $\theta=0$. The G/n curve therefore has a discontinuity at $x=\lambda$ if $f(0)$ is finite. If $f(0)=0$ but $f'(0)$ is finite the curve is continuous at $x=\lambda$ but its first derivative is discontinuous; the latter discontinuity also vanishes if $f'(0)$ is zero. In general, if $f(\theta)$ and its first $n-1$ derivatives are zero when $\theta=0$, then the G/n curve and its first $n-1$ derivatives are continuous and there is a discontinuity in the nth derivative.

If $f(\theta)$ is defined by the parameters P and Q as in Section 2.3, we have

$$[f(\theta_1)]^2=1+P\cos^2\theta_1+Q\cos^4\theta_1=1+P\left(\frac{\lambda}{x}\right)^2+Q\left(\frac{\lambda}{x}\right)^4$$

since in this particular case $\cos\theta_1=\lambda/x$. The gain per tier is therefore

$$\frac{G}{n}=\frac{1\cdot21883\frac{x}{\lambda}}{3+2P\left(\frac{\lambda}{x}\right)^2+2Q\left(\frac{\lambda}{x}\right)^4},\quad [\lambda<x<2\lambda] \tag{30}$$

Similar expressions may be derived for values of x within other limits, but they are not quoted here because spacings greater than two wavelengths are seldom used in practice.

2.7 *Non-uniform Horizontal Radiation Patterns*

For simplicity the foregoing argument has been confined to aerials which radiate equally in all directions normal to the axis of the array. The results can nevertheless be applied to aerials in which the h.r.p. is non-uniform, provided that all the tiers are identical.

Let the radiation pattern of a single tier be given by

$$E=\Psi(\theta,\phi)$$

where E is the field strength at some large constant distance and θ and ϕ are spherical polar angles. The power radiated in the region bounded by θ, $\theta+\delta\theta$, is proportional to

$$\frac{1}{2\pi}\left[\int_0^{2\pi}|\Psi(\theta,\phi)|^2 d\phi\right]\sin\theta\,\delta\theta \tag{31}$$

Instead of considering this aerial directly, we consider an equivalent aerial with a uniform h.r.p. and a v.r.p. which is the r.m.s. average $|\Psi(\theta,\phi)|$ with respect to ϕ. The v.r.p. of the equivalent aerial is therefore given by

$$f(\theta)=\sqrt{\frac{1}{2\pi}\int_0^{2\pi}|\Psi(\theta,\phi)|^2 d\phi} \tag{32}$$

The gain of the equivalent aerial, obtained by the methods discussed, is then applicable to the r.m.s. of the h.r.p. of the original aerial. Thus, if the h.r.p. is plotted in terms of field strength in polar co-ordinates and a circle is drawn to enclose the same area, the computed gain will correspond to this circle.

It may happen that the radiation pattern of one tier, $\Psi(\theta,\phi)$, is computed theoretically. In some cases, for example slotted cylinders and rings of dipoles, the result is

obtained in the form of a Fourier series in ϕ, with complex coefficients which are functions of θ. Let this series be

$$\Psi(\theta,\phi)=A_0(\theta)+A_1(\theta)\cos\phi+A_2(\theta)\cos 2\phi+\ldots \\ +B_1(\theta)\sin\phi+B_2(\theta)\sin 2\phi+\ldots \quad (33)$$

There is no need to sum this series in calculating the average v.r.p., since it follows from the orthogonality of the terms that

$$\frac{1}{2\pi}\int_0^{2\pi}|\Psi(\theta,\phi)|^2 d\phi=|A_0(\theta)|^2+\tfrac{1}{2}|A_1(\theta)|^2+\tfrac{1}{2}|A_2(\theta)|^2+\ldots \\ +\tfrac{1}{2}|B_1(\theta)|^2+\tfrac{1}{2}|B_2(\theta)|^2+\ldots \quad (34)$$

3. Discussion of the Results

Tables of relative mutual resistance and gain per tier were calculated on a digital computer for ten different kinds of source. Two computer programmes were written for this purpose. The first caused the computer to print out all the tables of relative mutual resistance. Each table was printed in three parts, divided vertically, since the teleprinter carriage would not accommodate the full width. These parts were joined together before reproducing the tables photographically. The first line of each table ($x<\lambda$) was omitted from the machine computation to avoid scaling difficulties, but was computed manually and inserted before reproduction.

The second programme was used to print the tables of gain per tier, including all the headings and data at the top of each table. It was written in a general form, and could be used to prepare additional tables if required. The values of P and Q, the first and last values of x/λ, the interval between successive values of x/λ, and the values of n are all specified by a data tape, and can be chosen within fairly wide limits.

The two programmes are quite independent; relative mutual resistances required for computing gains are computed by the gain programme as required. The values of P and Q were chosen so that they embraced the types of v.r.p. encountered in practice, and also included a number of specific types of aerials. The ten cases are listed below and the tables are reproduced in Appendix III.

TABLE 1

P	Q	*Type of aerial*
-3	$2\cdot25$	
-2	1	
$-1\cdot4294$	$0\cdot4294$	Collinear $\lambda/2$ dipoles
-1	0	Collinear doublets
0	-1	
3	-4	
-1	$0\cdot25$	
0	0	Isotropic sources
$0\cdot8806$	$0\cdot3598$	$\lambda/2$ dipole turnstiles
1	0	Doublet turnstiles

The values of P and Q for $\lambda/2$ dipoles are empirical; a note on their derivation is given in Appendix II. The v.r.p.s of all the sources are shown in Fig. 8.

Values of relative mutual resistance were tabulated at intervals of $0\cdot05\lambda$ for spacings up to $32\cdot95\lambda$. Although values are given for very small spacings, these should be used with discretion because they may be rendered invalid by the finite size of the radiating source. For example, the centres of collinear $\lambda/2$ dipoles cannot be placed closer together than $0\cdot5\lambda$ and mutual impedances for smaller spacings are therefore fictitious. For spacings greater than $0\cdot5\lambda$ the values given are correct provided that the current distribution on each dipole is not affected by the presence of the other. This assumption is valid for spacings greater than $0\cdot6\lambda$ between centres.

Gains were tabulated for arrays having up to thirty-two tiers. All the gains are quoted relative to a $\lambda/2$ dipole, and each table gives the gain of a single tier, denoted by G. There are two tables for each value of P and Q. For aerials of up to eight tiers the gain does not vary rapidly and it is therefore tabulated for large intervals over a wide range. The gain per tier of aerials having greater numbers of tiers approximates to that of aerials with an infinite number of tiers except for spacings close to $1\cdot0\lambda$. For these aerials, calculations were made, at closer intervals, over a restricted range in the region of $1\cdot0\lambda$, and are given in a separate table.

It should be noted that the gain tables for $\lambda/2$ dipole turnstiles give the mean gain. As the h.r.p. is not quite circular, the maximum gain (in the directions normal to the elements) is slightly greater. It can be obtained from the tables by multiplying by $1\cdot120$.

Appendix IV contains tables of the gains per tier of infinite arrays composed of the ten types of source considered, and Fig. 8 shows how these gains vary with inter-tier spacing. In general these curves have discontinuities at a spacing of one wavelength because of the formation of additional lobes. The gain decreases when the spacing exceeds one wavelength unless the radiation pattern of the source has zeros in the directions $\theta=0$ and π; this variation in gain would be accompanied by a rapid variation in input impedance.

Fig. 6 illustrates a typical way in which the gain per tier varies with the spacing and number of tiers. In this case (doublet turnstiles) each individual tier radiates a large field along the axis of the array and the discontinuity in the curve for an infinite number of tiers is large, while the curves for finite numbers of tiers fall sharply as the spacing approaches one wavelength. These curves show that care must be taken in deciding on the optimum spacing for arrays with large numbers of tiers. A spacing too close to one wavelength could result in a large variation in gain over the frequency band and a narrow impedance-bandwidth.

It will be noted that the curves do not rise smoothly before the sudden descent which occurs as the separation approaches one wavelength. Small fluctuations are present which are due to the rapid phase variation of the mutual impedance between the more distant elements. These fluc-

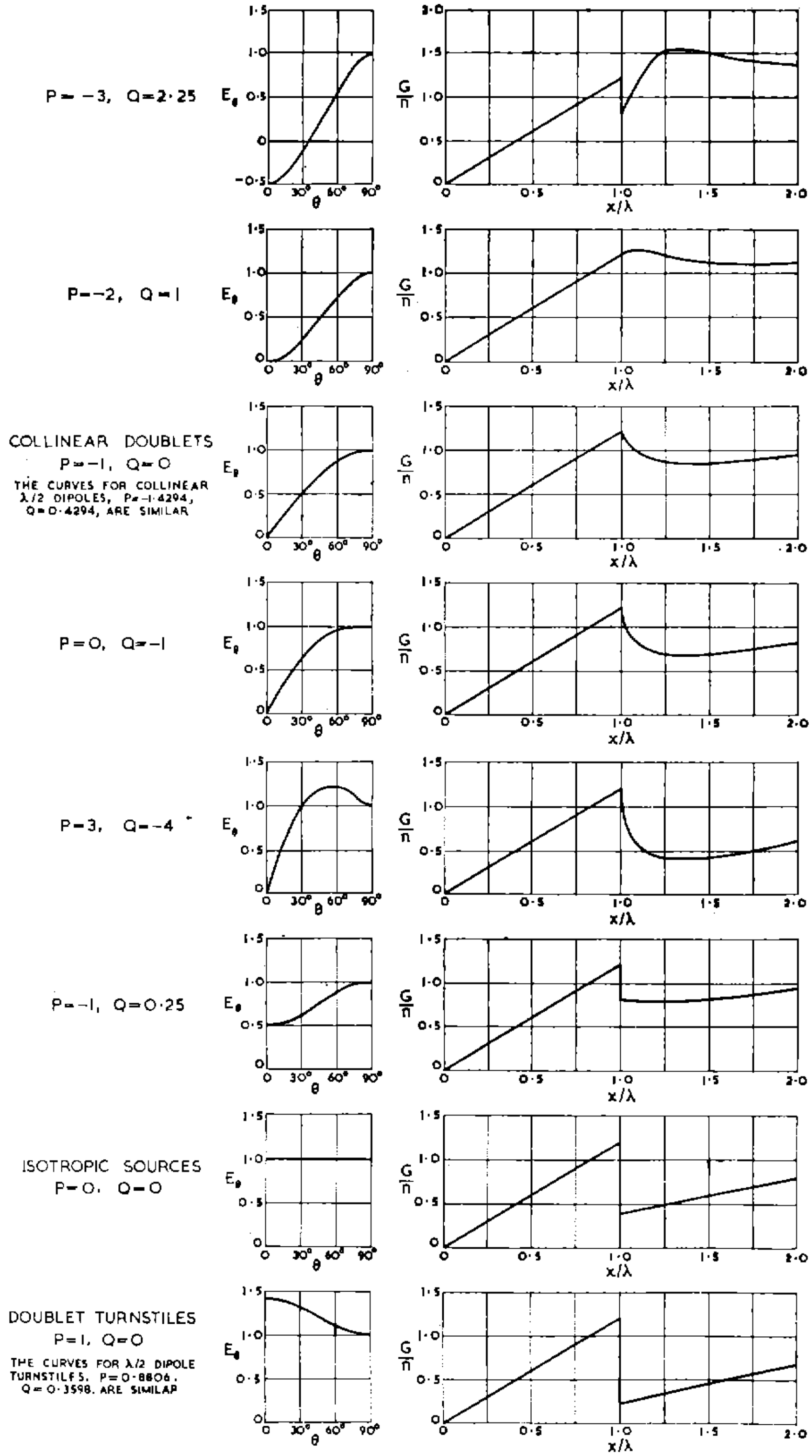

Fig. 8 — The v.r.p.s of the sources for which computations were carried out, and the gains per tier (relative to a λ/2 dipole) of corresponding infinite arrays

tuations become more rapid, but smaller in amplitude, as the number of tiers increases.

The relative mutual resistance tables for doublet and $\lambda/2$ dipole turnstiles may also be used, without modification, for parallel doublets and $\lambda/2$ dipoles, respectively. This is so because there is no mutual impedance between the two elements of a turnstile aerial and the relative mutual impedance between turnstiles is equal to that between the elements in each plane. For the same reason the gain tables for doublet turnstiles may also be applied to parallel doublets if the values are multiplied by 2, and approximate gains for parallel $\lambda/2$ dipoles may be derived from the tables for $\lambda/2$ dipole turnstiles by multiplying by $2 \cdot 240$; this factor is derived in Appendix II.

4. Conclusions and Practical Applications

The tables of mutual resistance and gain per tier should satisfy most requirements arising in the design of a v.h.f. aerial system comprising a number of identical tiers. If the tiers of the aerial are equally spaced and carry equal and co-phased radiating currents, the gain per tier can be read at once from the appropriate table. Nevertheless, it sometimes proves necessary to adopt unequal spacings between the tiers, usually for mechanical reasons. Moreover, it may be necessary to feed the tiers unequally in order to ensure satisfactory coverage in the immediate vicinity of the station. It will then be necessary to compute the gain from Equation (18), obtaining $R(x_{qr})$ from the tables of relative mutual resistance.

In general, the v.r.p. of a single tier cannot be represented exactly by Equation (11), but in most cases a reasonable fit can be obtained by using one of the pairs of values of P and Q listed in Table 1, for which the tables of gain per tier and relative mutual resistance have been computed. The corresponding v.r.p.s are shown on the left-hand side of Fig. 8. In deciding which of these curves gives the best fit, it should be borne in mind that the region of the curve which it is most important to fit accurately depends upon the number of tiers. For a small number of tiers, e.g. two to four, it is probably best to select the curve giving the best overall fit. For a larger number of tiers the selection of the appropriate curve is important only if x/λ is near to $1 \cdot 0$. In this case it is important to obtain a good fit for θ near to zero.

5. Acknowledgments

Mr J. W. Head was responsible for the computation of the tables of relative mutual resistance. Both computations were performed at the London Computer Centre of Ferranti Ltd. Thanks are due to Mrs M. J. Payne for advice in the preparation and running of the programme.

APPENDIX I

THE POWER RADIATED BY AN ARRAY OF SOURCES

Consider an array of n sources, and let the current and voltage at the input of the rth source be I_r and V_r (complex quantities). Let the mutual impedance between the qth and rth sources be Z_{qr}, Z_{rr} being the self-impedance of the rth source.

The input power to the rth source is $\mathrm{Re}(I_r^* V_r)$, where Re denotes 'the real part of' and the asterisk indicates the complex conjugate. This quantity is analogous to the scalar product of two vectors I_r and V_r.

The total input power is

$$W = \mathrm{Re} \sum_{r=1}^{n} I_r^* V_r \tag{35}$$

But

$$V_r = \sum_{q=1}^{n} Z_{qr} I_q$$

The total power is therefore

$$W = \mathrm{Re} \sum_{q=1}^{n} \sum_{r=1}^{n} Z_{qr} I_q I_r^* \tag{36}$$

Now the imaginary part of Z_{qr} has no effect on this result. For if $q \neq r$ the sum of the coefficients of Z_{qr} and Z_{rq} (which are equal) is $I_q^* I_r + I_q I_r^*$, a real quantity. The coefficient of Z_{rr} is $I_r I_r^*$, which is also a real quantity. Since the power is the real part of the sum of these products, the self- and mutual reactances do not affect the total radiated power. The total power is therefore equal to

$$W = \sum_{q=1}^{n} \sum_{r=1}^{n} R_{qr} I_q I_r^* \tag{37}$$

where R_{qr} is the mutual resistance.

APPENDIX II

THE CHOICE OF PARAMETERS FOR HALF-WAVE DIPOLES

1. Collinear $\lambda/2$ Dipoles

In representing the v.r.p. of a $\lambda/2$ dipole by an empirical formula in the form $[1+P\cos^2\theta+Q\cos^4\theta]^{\frac{1}{2}}$, the values of P and Q chosen were those for a source having

(a) the same gain as a $\lambda/2$ dipole

(b) zero field at $\theta=0$

In Section 2.4 it is shown that the gain of a source defined by the parameters P and Q relative to a $\lambda/2$ dipole is

$$G = \frac{1}{1\cdot 64092[1+P/3+Q/5]} \tag{38}$$

Condition (a) is therefore satisfied by the equation

$$1+P/3+Q/5 = 0\cdot 60941 \tag{39}$$

Condition (b) is satisfied by

$$1+P+Q=0 \tag{40}$$

The solution of these two equations is

$$P=-1\cdot 4294 \quad Q=0\cdot 4294$$

The v.r.p. defined by these parameters agrees closely with the exact v.r.p. of a $\lambda/2$ dipole. At $\theta=45°$, for example, the error in field is only 2 per cent.

2. $\lambda/2$ Dipole Turnstiles

A turnstile aerial consists of a pair of crossed radiators fed with equal currents in phase quadrature. When the radiators are doublets, the field strength in the plane containing the elements is the same in all directions. A $\lambda/2$ dipole turnstile, however, does not have an omnidirectional h.r.p. and must therefore be replaced by an equivalent aerial, as described in Section 2.7. The v.r.p. of the equivalent aerial is defined by Equation (32) and a very close approximation is achieved with a source which has

(a) the same mean gain (or r.m.s. field) in the plane containing the elements ($\theta=\pi/2$)

(b) the same gain along the turnstile axis ($\theta=0$)

Now the r.m.s. field in the plane containing the elements is

$$f\left(\frac{\pi}{2}\right) = \sqrt{\frac{1}{2\pi}\int_0^{2\pi}\left|\Psi\left(\frac{\pi}{2},\phi\right)\right|^2 d\phi} \tag{41}$$

where $$\Psi\left(\frac{\pi}{2},\phi\right) = \frac{\cos\left(\frac{\pi}{2}\cos\phi\right)}{\sin\phi} + j\,\frac{\cos\left(\frac{\pi}{2}\sin\phi\right)}{\cos\phi}$$

The integral cannot be solved analytically in this form. A solution is, however, possible if the radiation pattern is expressed in terms of the parameters for a $\lambda/2$ dipole derived earlier in the Appendix. Denoting them by P_1 and Q_1 ($P_1=-1\cdot4294$, $Q_1=0\cdot4294$) we have

$$\Psi\left(\frac{\pi}{2},\phi\right)=\sqrt{1+P_1\cos^2\phi+Q_1\cos^4\phi}+j\sqrt{1+P_1\sin^2\phi+Q_1\sin^4\phi} \tag{42}$$

The solution of the integral is then

$$\frac{1}{2\pi}\int_0^{2\pi}\left|\Psi\left(\frac{\pi}{2},\phi\right)\right|^2 d\phi=\frac{1}{2\pi}\int_0^{2\pi}[2+P_1+Q_1(\cos^4\phi+\sin^4\phi)]d\phi$$
$$=2+P_1+0\cdot75Q_1$$
$$=0\cdot8927$$

The maximum gain in the plane containing the turnstile elements is equal to one half that of a $\lambda/2$ dipole, since the power is shared equally between the two elements. The mean gain of the equivalent source is therefore $0\cdot5\times 0\cdot8927$ relative to a $\lambda/2$ dipole or $0\cdot5\times0\cdot8927\times1\cdot64092=0\cdot7324$ relative to an isotropic source.

Now it is shown in Section 2.4 that the gain in the direction $\theta=\pi/2$ of a single source defined by the parameters P and Q is

$$\frac{1}{1+P/3+Q/5}$$

relative to an isotropic source. Condition (a) is therefore satisfied by the relation

$$\frac{1}{1+P/3+Q/5}=0\cdot7324 \tag{43}$$

Along the turnstile axis both elements contribute equally to the radiated power. The gain in this direction is therefore equal to that of a $\lambda/2$ dipole, i.e. $1\cdot64092$ relative to an isotropic source.

The gain of a source defined by P and Q in this direction is equal to the product of the gain in the plane perpendicular to the axis and the square of the ratios of the fields radiated in the directions $\theta=0$ and $\pi/2$. Its value is therefore

$$\frac{1}{1+P/3+Q/5}\left\{\frac{f(0)}{f(\pi/2)}\right\}^2=\frac{1+P+Q}{1+P/3+Q/5}$$

Condition (b) is therefore satisfied by the equation

$$\frac{1+P+Q}{1+P/3+Q/5}=1\cdot64092 \tag{44}$$

Equations (43) and (44) lead to the result that $P=0\cdot8806$, $Q=0\cdot3598$.

In an array of turnstiles there is no mutual impedance between the two planes containing the elements. The elements in each plane may therefore be considered separately and this fact enables us to derive the gain of arrays of parallel doublets and dipoles from the tables. Since the power radiated by a turnstile is shared equally between the two elements, the gain of an array of parallel doublets is exactly twice that of a similar array of doublet turnstiles. The same multiplying factor cannot be used for parallel $\lambda/2$ dipoles, since the gain tables for $\lambda/2$ dipole turnstiles give the r.m.s. gain. The correct multiplying factor is $2/0\cdot8927=2\cdot240$; this is twice the ratio of the maximum gain to the r.m.s. gain of a $\lambda/2$ dipole turnstile.

APPENDIX III

TABLES SHOWING RELATIVE MUTUAL RESISTANCE AND AERIAL GAIN PER TIER

Notes on the use of the Tables

The way in which the tables may be used to determine the gain of a multi-tiered aerial is summarized for convenience below.

1. Determine the appropriate values of P and Q from the measured or theoretical v.r.p. of a single tier, using Fig. 8, page 13. For an aerial having a small number of tiers, e.g. 2 to 4, choose the curve giving the best overall fit. For larger numbers of tiers choose the curve giving the best fit for θ near to 0°, the curves being scaled to coincide at $\theta=90°$.
2. If the tiers of the aerial are all equally spaced and carry equal co-phased currents the gain may be obtained directly from the 'Aerial Gain per Tier' tables. The gain of the aerial is equal to the value derived from the tables multiplied by the number of tiers. It is stated as a power ratio, the reference being a $\lambda/2$ dipole.
3. If the tiers are not equally spaced or do not carry equal currents, values obtained from the 'Relative Mutual Resistance' tables must be substituted in either equation (18) or equation (19). These give the gain relative to a single tier; the gain relative to a $\lambda/2$ dipole may be obtained by multiplying the result by the gain of a single tier, denoted by G at the top of the 'Aerial Gain per Tier' tables.
4. Either method gives the mean or r.m.s. gain if the aerial does not have an omnidirectional h.r.p.

RELATIVE MUTUAL RESISTANCE

P = -3·0   Q = 2·25

X/λ	·00	·05	·10	·15	·20	·25	·30	·35	·40	·45	·50	·55	·60	·65	·70	·75	·80	·85	·90	·95
0	+1.0000	+0.9940	+0.9763	+0.9475	+0.9087	+0.8613	+0.8070	+0.7476	+0.6848	+0.6206	+0.5564	+0.4938	+0.4339	+0.3773	+0.3248	+0.2764	+0.2322	+0.1920	+0.1555	+0.1222
1	+0.0919	+0.0642	+0.0390	+0.0162	-0.0040	-0.0216	-0.0362	-0.0475	-0.0553	-0.0595	-0.0598	-0.0566	-0.0500	-0.0406	-0.0291	-0.0162	-0.0028	+0.0101	+0.0215	+0.0309
2	+0.0374	+0.0408	+0.0408	+0.0375	+0.0314	+0.0230	+0.0130	+0.0024	-0.0081	-0.0175	-0.0250	-0.0302	-0.0326	-0.0321	-0.0288	-0.0232	-0.0157	-0.0070	+0.0019	+0.0105
3	+0.0178	+0.0233	+0.0266	+0.0274	+0.0257	+0.0218	+0.0159	+0.0088	+0.0011	-0.0065	-0.0133	-0.0187	-0.0222	-0.0237	-0.0229	-0.0200	-0.0154	-0.0094	-0.0028	+0.0040
4	+0.0103	+0.0154	+0.0190	+0.0207	+0.0205	+0.0184	+0.0146	+0.0095	+0.0036	-0.0024	-0.0082	-0.0130	-0.0165	-0.0184	-0.0185	-0.0169	-0.0137	-0.0093	-0.0041	+0.0014
5	+0.0066	+0.0111	+0.0145	+0.0165	+0.0168	+0.0155	+0.0128	+0.0090	+0.0043	-0.0007	-0.0055	-0.0097	-0.0129	-0.0149	-0.0154	-0.0144	-0.0121	-0.0086	-0.0044	+0.0002
6	+0.0046	+0.0086	+0.0117	+0.0136	+0.0142	+0.0134	+0.0113	+0.0082	+0.0044	+0.0002	-0.0040	-0.0077	-0.0106	-0.0125	-0.0131	-0.0125	-0.0107	-0.0079	-0.0044	-0.0005
7	+0.0034	+0.0069	+0.0097	+0.0115	+0.0122	+0.0117	+0.0101	+0.0075	+0.0043	+0.0007	-0.0030	-0.0063	-0.0089	-0.0107	-0.0114	-0.0110	-0.0096	-0.0072	-0.0042	-0.0008
8	+0.0026	+0.0057	+0.0083	+0.0100	+0.0107	+0.0104	+0.0091	+0.0069	+0.0041	+0.0009	-0.0023	-0.0053	-0.0077	-0.0094	-0.0101	-0.0098	-0.0086	-0.0066	-0.0040	-0.0010
9	+0.0021	+0.0049	+0.0072	+0.0088	+0.0095	+0.0093	+0.0082	+0.0063	+0.0039	+0.0010	-0.0019	-0.0045	-0.0068	-0.0083	-0.0090	-0.0089	-0.0079	-0.0061	-0.0037	-0.0011
10	+0.0017	+0.0042	+0.0064	+0.0079	+0.0086	+0.0085	+0.0075	+0.0059	+0.0036	+0.0011	-0.0015	-0.0040	-0.0060	-0.0075	-0.0082	-0.0081	-0.0072	-0.0056	-0.0035	-0.0011
11	+0.0014	+0.0037	+0.0057	+0.0071	+0.0078	+0.0077	+0.0069	+0.0054	+0.0034	+0.0011	-0.0013	-0.0035	-0.0054	-0.0068	-0.0075	-0.0074	-0.0066	-0.0052	-0.0033	-0.0011
12	+0.0012	+0.0033	+0.0052	+0.0065	+0.0071	+0.0071	+0.0064	+0.0051	+0.0032	+0.0011	-0.0011	-0.0032	-0.0049	-0.0062	-0.0069	-0.0068	-0.0062	-0.0049	-0.0032	-0.0011
13	+0.0010	+0.0030	+0.0047	+0.0059	+0.0066	+0.0066	+0.0060	+0.0047	+0.0031	+0.0011	-0.0009	-0.0029	-0.0045	-0.0057	-0.0063	-0.0064	-0.0058	-0.0046	-0.0030	-0.0011
14	+0.0009	+0.0027	+0.0043	+0.0055	+0.0061	+0.0061	+0.0056	+0.0045	+0.0029	+0.0011	-0.0008	-0.0026	-0.0042	-0.0053	-0.0059	-0.0059	-0.0054	-0.0043	-0.0028	-0.0011
15	+0.0007	+0.0025	+0.0040	+0.0051	+0.0057	+0.0057	+0.0052	+0.0042	+0.0028	+0.0011	-0.0007	-0.0024	-0.0039	-0.0049	-0.0055	-0.0056	-0.0051	-0.0041	-0.0027	-0.0011
16	+0.0007	+0.0023	+0.0037	+0.0048	+0.0053	+0.0054	+0.0049	+0.0040	+0.0026	+0.0011	-0.0006	-0.0022	-0.0036	-0.0046	-0.0052	-0.0052	-0.0048	-0.0039	-0.0026	-0.0010
17	+0.0006	+0.0021	+0.0035	+0.0045	+0.0050	+0.0051	+0.0047	+0.0038	+0.0025	+0.0010	-0.0006	-0.0021	-0.0034	-0.0043	-0.0049	-0.0049	-0.0045	-0.0037	-0.0025	-0.0010
18	+0.0005	+0.0020	+0.0033	+0.0042	+0.0047	+0.0048	+0.0044	+0.0036	+0.0024	+0.0010	-0.0005	-0.0019	-0.0032	-0.0041	-0.0046	-0.0047	-0.0043	-0.0035	-0.0024	-0.0010
19	+0.0005	+0.0019	+0.0031	+0.0040	+0.0045	+0.0046	+0.0042	+0.0034	+0.0023	+0.0010	-0.0004	-0.0018	-0.0030	-0.0039	-0.0044	-0.0045	-0.0041	-0.0033	-0.0023	-0.0010
20	+0.0004	+0.0018	+0.0029	+0.0038	+0.0043	+0.0043	+0.0040	+0.0033	+0.0022	+0.0009	-0.0004	-0.0017	-0.0028	-0.0037	-0.0042	-0.0042	-0.0039	-0.0032	-0.0022	-0.0009
21	+0.0004	+0.0017	+0.0028	+0.0036	+0.0041	+0.0041	+0.0038	+0.0031	+0.0021	+0.0009	-0.0004	-0.0016	-0.0027	-0.0035	-0.0040	-0.0040	-0.0037	-0.0031	-0.0021	-0.0009
22	+0.0003	+0.0016	+0.0026	+0.0034	+0.0039	+0.0040	+0.0036	+0.0030	+0.0020	+0.0009	-0.0003	-0.0015	-0.0026	-0.0033	-0.0038	-0.0039	-0.0036	-0.0029	-0.0020	-0.0009
23	+0.0003	+0.0015	+0.0025	+0.0033	+0.0037	+0.0038	+0.0035	+0.0029	+0.0020	+0.0009	-0.0003	-0.0014	-0.0024	-0.0032	-0.0036	-0.0037	-0.0034	-0.0028	-0.0019	-0.0009
24	+0.0003	+0.0014	+0.0024	+0.0031	+0.0036	+0.0036	+0.0034	+0.0028	+0.0019	+0.0008	-0.0003	-0.0014	-0.0023	-0.0031	-0.0035	-0.0036	-0.0033	-0.0027	-0.0019	-0.0008
25	+0.0003	+0.0013	+0.0023	+0.0030	+0.0034	+0.0035	+0.0032	+0.0027	+0.0018	+0.0008	-0.0003	-0.0013	-0.0022	-0.0029	-0.0033	-0.0034	-0.0032	-0.0026	-0.0018	-0.0008
26	+0.0002	+0.0013	+0.0022	+0.0029	+0.0033	+0.0034	+0.0031	+0.0026	+0.0018	+0.0008	-0.0002	-0.0013	-0.0021	-0.0028	-0.0032	-0.0033	-0.0031	-0.0025	-0.0017	-0.0008
27	+0.0002	+0.0012	+0.0021	+0.0028	+0.0032	+0.0032	+0.0030	+0.0025	+0.0017	+0.0008	-0.0002	-0.0012	-0.0021	-0.0027	-0.0031	-0.0032	-0.0029	-0.0024	-0.0017	-0.0008
28	+0.0002	+0.0012	+0.0020	+0.0027	+0.0030	+0.0031	+0.0029	+0.0024	+0.0017	+0.0008	-0.0002	-0.0012	-0.0020	-0.0026	-0.0030	-0.0031	-0.0028	-0.0024	-0.0016	-0.0007
29	+0.0002	+0.0011	+0.0019	+0.0026	+0.0029	+0.0030	+0.0028	+0.0023	+0.0016	+0.0007	-0.0002	-0.0011	-0.0019	-0.0025	-0.0029	-0.0030	-0.0028	-0.0023	-0.0016	-0.0007
30	+0.0002	+0.0011	+0.0019	+0.0025	+0.0028	+0.0029	+0.0027	+0.0022	+0.0016	+0.0007	-0.0002	-0.0011	-0.0018	-0.0024	-0.0028	-0.0029	-0.0027	-0.0022	-0.0015	-0.0007
31	+0.0002	+0.0010	+0.0018	+0.0024	+0.0027	+0.0028	+0.0026	+0.0022	+0.0015	+0.0007	-0.0002	-0.0010	-0.0018	-0.0024	-0.0027	-0.0028	-0.0026	-0.0021	-0.0015	-0.0007
32	+0.0002	+0.0010	+0.0017	+0.0023	+0.0027	+0.0027	+0.0025	+0.0021	+0.0015	+0.0007	-0.0002	-0.0010	-0.0017	-0.0023	-0.0026	-0.0027	-0.0025	-0.0021	-0.0015	-0.0007

AERIAL GAIN PER TIER

P = −3.0   Q = 2.25   G = 1.3543

INTER-TIER SPACING	NUMBER OF TIERS 2	3	4	5	6	8
0.25	0.7276	0.5375	0.4534	0.4099	0.3861	0.3631
0.3	0.7494	0.5726	0.4975	0.4615	0.4431	0.4209
0.35	0.7749	0.6119	0.5465	0.5179	0.5014	0.4795
0.4	0.8038	0.6549	0.5999	0.5760	0.5582	0.5392
0.45	0.8357	0.7013	0.6566	0.6327	0.6156	0.5975
0.5	0.8701	0.7510	0.7140	0.6883	0.6749	0.6571
0.55	0.9066	0.8040	0.7697	0.7453	0.7330	0.7160
0.6	0.9445	0.8594	0.8231	0.8043	0.7894	0.7743
0.65	0.9832	0.9157	0.8764	0.8615	0.8480	0.83[illegible]0
0.7	1.0223	0.9700	0.9325	0.9153	0.9068	0.8910
0.75	1.0610	1.0193	0.9912	0.9701	0.9611	0.9501
0.8	1.0990	1.0611	1.0463	1.0296	1.0161	1.0072
0.85	1.1361	1.0951	1.0888	1.0846	1.0766	1.0606
0.9	1.1720	1.1235	1.1137	1.1161	1.1202	1.1207
0.95	1.2068	1.1503	1.1273	1.1196	1.1197	1.1299
1.0	1.2403	1.1802	1.1437	1.1190	1.1011	1.0769
1.05	1.2726	1.2170	1.1768	1.1460	1.1214	1.0856
1.1	1.3034	1.2622	1.2335	1.2153	1.2055	1.2020
1.15	1.3326	1.3144	1.3095	1.3150	1.3249	1.3384
1.2	1.3597	1.3690	1.3893	1.4098	1.4215	1.4257
1.25	1.3841	1.4188	1.4522	1.4687	1.4728	1.4843
1.3	1.4051	1.4561	1.4853	1.4922	1.4991	1.5128
1.35	1.4218	1.4761	1.4921	1.4990	1.5106	1.5179
1.4	1.4336	1.4788	1.4856	1.4983	1.5049	1.5132
1.45	1.4399	1.4688	1.4760	1.4882	1.4901	1.4975
1.5	1.4405	1.4529	1.4657	1.4705	1.4753	1.4803
1.55	1.4355	1.4372	1.4522	1.4525	1.4584	1.4617
1.6	1.4256	1.4249	1.4348	1.4382	1.4391	1.4425
1.65	1.4116	1.4159	1.4170	1.4240	1.4235	1.4271
1.7	1.3948	1.4078	1.4037	1.4075	1.4111	1.4107
1.75	1.3765	1.3967	1.3958	1.3933	1.3963	1.3986

INTER-TIER SPACING	NUMBER OF TIERS 8	10	12	16	20	24	32
0.7	0.8910	0.8839	0.8786	0.8722	0.8682	0.8656	0.8625
0.72	0.9141	0.9078	0.9018	0.8958	0.8922	0.8898	0.8866
0.74	0.9380	0.9309	0.9255	0.9195	0.9159	0.9136	0.9107
0.76	0.9622	0.9533	0.9498	0.9437	0.9401	0.9378	0.9349
0.78	0.9855	0.9765	0.9731	0.9671	0.9636	0.9614	0.9588
0.8	1.0072	1.0007	0.9954	0.9903	0.9876	0.9856	0.9828
0.82	1.0279	1.0247	1.0186	1.0147	1.0114	1.0090	1.0069
0.84	1.0492	1.0464	1.0431	1.0377	1.0344	1.0332	1.0305
0.86	1.0726	1.0665	1.0660	1.0599	1.0587	1.0561	1.0543
0.88	1.0977	1.0880	1.0858	1.0843	1.0807	1.0803	1.0783
0.9	1.1207	1.1129	1.1064	1.1063	1.1042	1.1022	1.1009
0.92	1.1352	1.1364	1.1316	1.1243	1.1264	1.1259	1.1242
0.94	1.1355	1.1466	1.1519	1.1486	1.1434	1.1445	1.1466
0.96	1.1211	1.1329	1.1452	1.1625	1.1676	1.1653	1.1618
0.98	1.0982	1.0985	1.1034	1.1191	1.1368	1.1529	1.1743
1.0	1.0769	1.0611	1.0498	1.0349	1.0252	1.0185	1.0095
1.02	1.0669	1.0402	1.0188	0.9858	0.9620	0.9448	0.9247
1.04	1.0744	1.0475	1.0283	1.0065	0.9986	0.9970	0.9945
1.06	1.1016	1.0840	1.0759	1.0734	1.0731	1.0691	1.0644
1.08	1.1462	1.1418	1.1433	1.1439	1.1386	1.1375	1.1362
1.1	1.2020	1.2069	1.2094	1.2047	1.2049	1.2051	1.2045
1.12	1.2608	1.2667	1.2653	1.2645	1.2663	1.2657	1.2663
1.14	1.3148	1.3166	1.3151	1.3202	1.3200	1.3219	1.3228
1.16	1.3576	1.3592	1.3625	1.3665	1.3695	1.3700	1.3723
1.18	1.3957	1.3981	1.4045	1.4073	1.4102	1.4126	1.4143
1.2	1.4257	1.4332	1.4378	1.4428	1.4452	1.4470	1.4499
1.22	1.4518	1.4618	1.4640	1.4701	1.4737	1.4759	1.4785
1.24	1.4746	1.4828	1.4860	1.4919	1.4954	1.4978	1.5007
1.26	1.4928	1.4980	1.5039	1.5093	1.5127	1.5149	1.5177
1.28	1.5054	1.5097	1.5157	1.5209	1.5241	1.5264	1.5294
1.3	1.5128	1.5187	1.5226	1.5282	1.5319	1.5343	1.5369

RELATIVE MUTUAL RESISTANCE

P = -2·0   Q = 1·0

X/λ	·00	·05	·10	·15	·20	·25	·30	·35	·40	·45	·50	·55	·60	·65	·70	·75	·80	·85	·90	·95
0	+1·0000	+0·9930	+0·9721	+0·9381	+0·8920	+0·8354	+0·7700	+0·6977	+0·6208	+0·5415	+0·4620	+0·3842	+0·3101	+0·2412	+0·1788	+0·1240	+0·0772	+0·0388	+0·0086	-0·0138
1	-0·0289	-0·0376	-0·0410	-0·0400	-0·0358	-0·0295	-0·0219	-0·0139	-0·0064	+0·0003	+0·0057	+0·0096	+0·0120	+0·0129	+0·0125	+0·0110	+0·0088	+0·0061	+0·0033	+0·0006
2	-0·0018	-0·0037	-0·0050	-0·0056	-0·0057	-0·0052	-0·0043	-0·0032	-0·0018	-0·0005	+0·0007	+0·0018	+0·0025	+0·0029	+0·0031	+0·0029	+0·0024	+0·0018	+0·0011	+0·0004
3	-0·0004	-0·0010	-0·0014	-0·0017	-0·0018	-0·0017	-0·0015	-0·0012	-0·0007	-0·0003	+0·0002	+0·0006	+0·0009	+0·0011	+0·0012	+0·0011	+0·0010	+0·0008	+0·0005	+0·0002
4	-0·0001	-0·0004	-0·0006	-0·0007	-0·0008	-0·0008	-0·0007	-0·0005	-0·0004	-0·0001	+0·0001	+0·0003	+0·0004	+0·0005	+0·0006	+0·0006	+0·0005	+0·0004	+0·0003	+0·0001
5	-0·0000	-0·0002	-0·0003	-0·0004	-0·0004	-0·0004	-0·0004	-0·0003	-0·0002	-0·0001	+0·0000	+0·0001	+0·0002	+0·0003	+0·0003	+0·0003	+0·0003	+0·0002	+0·0002	+0·0001
6	-0·0000	-0·0001	-0·0002	-0·0002	-0·0002	-0·0002	-0·0002	-0·0002	-0·0001	-0·0001	+0·0000	+0·0001	+0·0001	+0·0002	+0·0002	+0·0002	+0·0002	+0·0001	+0·0001	+0·0000
7	-0·0000	-0·0001	-0·0001	-0·0001	-0·0002	-0·0002	-0·0001	-0·0001	-0·0001	-0·0000	+0·0000	+0·0001	+0·0001	+0·0001	+0·0001	+0·0001	+0·0001	+0·0001	+0·0001	+0·0000
8	-0·0000	-0·0000	-0·0001	-0·0001	-0·0001	-0·0001	-0·0001	-0·0001	-0·0001	-0·0000	+0·0000	+0·0000	+0·0001	+0·0001	+0·0001	+0·0001	+0·0001	+0·0001	+0·0000	+0·0000
9	-0·0000	-0·0000	-0·0001	-0·0001	-0·0001	-0·0001	-0·0001	-0·0001	-0·0000	-0·0000	+0·0000	+0·0000	+0·0000	+0·0001	+0·0001	+0·0001	+0·0001	+0·0000	+0·0000	+0·0000
10	-0·0000	-0·0000	-0·0000	-0·0000	-0·0001	-0·0001	-0·0001	-0·0000	-0·0000	-0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000
11	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000
12	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000
13	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000
14	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000
15	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000
16	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000
17	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000
18	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000
19	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000
20	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000
21	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000
22	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000
23	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000
24	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000
25	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000
26	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000
27	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000
28	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000
29	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000
30	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000
31	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000
32	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	-0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000	+0·0000

AERIAL GAIN PER TIER

P = -2·0   Q = 1·0   G = 1·1427

INTER-TIER SPACING / NUMBER OF TIERS

	2	3	4	5	6	8
0·25	0·6226	0·4718	0·4115	0·3836	0·3682	0·3500
0·3	0·6456	0·5116	0·4627	0·4401	0·4258	0·4088
0·35	0·6730	0·5575	0·5178	0·4972	0·4835	0·4680
0·4	0·7050	0·6080	0·5740	0·5541	0·5417	0·5271
0·45	0·7412	0·6613	0·6299	0·6113	0·6001	0·5862
0·5	0·7816	0·7156	0·6855	0·6689	0·6581	0·6452
0·55	0·8255	0·7695	0·7411	0·7262	0·7161	0·7041
0·6	0·8722	0·8223	0·7970	0·7830	0·7739	0·7628
0·65	0·9206	0·8743	0·8526	0·8395	0·8313	0·8212
0·7	0·9693	0·9258	0·9073	0·8959	0·8883	0·8793
0·75	1·0166	0·9774	0·9610	0·9515	0·9450	0·9371
0·8	1·0608	1·0285	1·0140	1·0061	1·0009	0·9943
0·85	1·1000	1·0730	1·0664	1·0599	1·0558	1·0509
0·9	1·1329	1·1232	1·1168	1·1125	1·1097	1·1064
0·95	1·1586	1·1614	1·1617	1·1615	1·1611	1·1603
1·0	1·1766	1·1899	1·1969	1·2011	1·2040	1·2077
1·05	1·1873	1·2072	1·2185	1·2258	1·2309	1·2376
1·1	1·1915	1·2136	1·2259	1·2336	1·2388	1·2452
1·15	1·1903	1·2108	1·2214	1·2277	1·2318	1·2369
1·2	1·1851	1·2015	1·2093	1·2138	1·2168	1·2207
1·25	1·1773	1·1888	1·1938	1·1969	1·1991	1·2018
1·3	1·1682	1·1750	1·1781	1·1801	1·1815	1·1832
1·35	1·1588	1·1619	1·1637	1·1648	1·1655	1·1664
1·4	1·1500	1·1505	1·1513	1·1516	1·1519	1·1522
1·45	1·1423	1·1413	1·1412	1·1409	1·1408	1·1407
1·5	1·1362	1·1343	1·1333	1·1327	1·1324	1·1319
1·55	1·1318	1·1293	1·1277	1·1269	1·1263	1·1256
1·6	1·1291	1·1260	1·1242	1·1232	1·1225	1·1216
1·65	1·1281	1·1245	1·1226	1·1214	1·1207	1·1197
1·7	1·1286	1·1245	1·1226	1·1214	1·1206	1·1197
1·75	1·1302	1·1260	1·1241	1·1230	1·1222	1·1213

INTER-TIER SPACING / NUMBER OF TIERS

	8	10	12	15	20	24	32
0·7	0·8793	0·8740	0·8704	0·8661	0·8634	0·8617	0·8596
0·72	0·9025	0·8974	0·8940	0·8898	0·8874	0·8857	0·8837
0·74	0·9256	0·9207	0·9175	0·9136	0·9112	0·9097	0·9077
0·76	0·9485	0·9440	0·9410	0·9373	0·9351	0·9336	0·9318
0·78	0·9715	0·9673	0·9644	0·9610	0·9589	0·9575	0·9558
0·8	0·9943	0·9904	0·9878	0·9846	0·9827	0·9814	0·9798
0·82	1·0171	1·0134	1·0111	1·0082	1·0064	1·0052	1·0038
0·84	1·0397	1·0354	1·0343	1·0317	1·0301	1·0290	1·0277
0·86	1·0621	1·0593	1·0574	1·0551	1·0537	1·0528	1·0516
0·88	1·0843	1·0820	1·0804	1·0784	1·0773	1·0765	1·0755
0·9	1·1064	1·1045	1·1033	1·1017	1·1007	1·1001	1·0993
0·92	1·1282	1·1268	1·1259	1·1248	1·1241	1·1236	1·1230
0·94	1·1498	1·1489	1·1483	1·1476	1·1473	1·1470	1·1467
0·96	1·1706	1·1705	1·1704	1·1703	1·1702	1·1702	1·1702
0·98	1·1902	1·1912	1·1918	1·1925	1·1929	1·1931	1·1935
1·0	1·2077	1·2099	1·2114	1·2132	1·2143	1·2151	1·2160
1·02	1·2223	1·2255	1·2278	1·2306	1·2324	1·2336	1·2351
1·04	1·2334	1·2373	1·2400	1·2433	1·2453	1·2467	1·2483
1·06	1·2408	1·2450	1·2477	1·2511	1·2531	1·2545	1·2562
1·08	1·2446	1·2486	1·2513	1·2546	1·2567	1·2580	1·2597
1·1	1·2452	1·2490	1·2516	1·2548	1·2567	1·2580	1·2596
1·12	1·2433	1·2468	1·2492	1·2522	1·2540	1·2552	1·2568
1·14	1·2394	1·2427	1·2449	1·2476	1·2493	1·2504	1·2518
1·16	1·2341	1·2370	1·2390	1·2415	1·2430	1·2440	1·2453
1·18	1·2277	1·2304	1·2321	1·2344	1·2357	1·2366	1·2377
1·2	1·2207	1·2230	1·2246	1·2265	1·2277	1·2285	1·2295
1·22	1·2133	1·2153	1·2166	1·2184	1·2194	1·2201	1·2209
1·24	1·2056	1·2074	1·2085	1·2100	1·2109	1·2115	1·2122
1·26	1·1980	1·1995	1·2005	1·2017	1·2025	1·2030	1·2036
1·28	1·1905	1·1917	1·1925	1·1936	1·1942	1·1946	1·1951
1·3	1·1832	1·1842	1·1849	1·1857	1·1863	1·1866	1·1870

RELATIVE MUTUAL RESISTANCE

COLLINEAR λ/2 DIPOLES

P = -1·4294 Q = 0·4294

X/λ	·00	·05	·10	·15	·20	·25	·30	·35	·40	·45	·50	·55	·60	·65	·70	·75	·80	·85	·90	·95
0	+1.0000	+0.9912	+0.9652	+0.9230	+0.8663	+0.7971	+0.7181	+0.6322	+0.5425	+0.4519	+0.3633	+0.2795	+0.2026	+0.1344	+0.0762	+0.0287	-0.0079	-0.0340	-0.0502	-0.0579
1	-0.0583	-0.0539	-0.0438	-0.0321	-0.0195	-0.0072	+0.0037	+0.0125	+0.0198	+0.0223	+0.0232	+0.0218	+0.0184	+0.0137	+0.0083	+0.0027	-0.0025	-0.0068	-0.0100	-0.0120
2	-0.0125	-0.0118	-0.0101	-0.0075	-0.0045	-0.0013	+0.0017	+0.0043	+0.0063	+0.0075	+0.0079	+0.0075	+0.0064	+0.0047	+0.0028	+0.0007	-0.0013	-0.0030	-0.0043	-0.0051
3	-0.0054	-0.0051	-0.0044	-0.0033	-0.0019	-0.0004	+0.0010	+0.0022	+0.0032	+0.0037	+0.0039	+0.0037	+0.0032	+0.0024	+0.0014	+0.0003	-0.0008	-0.0017	-0.0024	-0.0029
4	-0.0030	-0.0029	-0.0024	-0.0018	-0.0010	-0.0002	+0.0006	+0.0013	+0.0019	+0.0023	+0.0024	+0.0023	+0.0019	+0.0014	+0.0008	+0.0001	-0.0005	-0.0011	-0.0015	-0.0018
5	-0.0019	-0.0018	-0.0016	-0.0011	-0.0006	-0.0001	+0.0004	+0.0009	+0.0013	+0.0015	+0.0016	+0.0015	+0.0013	+0.0009	+0.0005	+0.0001	-0.0004	-0.0008	-0.0011	-0.0013
6	-0.0013	-0.0013	-0.0011	-0.0008	-0.0004	-0.0001	+0.0003	+0.0006	+0.0009	+0.0011	+0.0011	+0.0011	+0.0009	+0.0007	+0.0004	+0.0000	-0.0003	-0.0006	-0.0008	-0.0009
7	-0.0010	-0.0009	-0.0008	-0.0006	-0.0003	-0.0000	+0.0002	+0.0005	+0.0007	+0.0008	+0.0008	+0.0008	+0.0007	+0.0005	+0.0003	+0.0000	-0.0002	-0.0004	-0.0006	-0.0007
8	-0.0007	-0.0007	-0.0006	-0.0004	-0.0002	-0.0000	+0.0002	+0.0004	+0.0005	+0.0006	+0.0007	+0.0006	+0.0005	+0.0004	+0.0002	+0.0000	-0.0002	-0.0003	-0.0005	-0.0006
9	-0.0006	-0.0006	-0.0005	-0.0003	-0.0002	-0.0000	+0.0002	+0.0003	+0.0004	+0.0005	+0.0005	+0.0005	+0.0004	+0.0003	+0.0002	+0.0000	-0.0001	-0.0003	-0.0004	-0.0005
10	-0.0005	-0.0005	-0.0004	-0.0003	-0.0002	-0.0000	+0.0001	+0.0002	+0.0003	+0.0004	+0.0004	+0.0004	+0.0003	+0.0003	+0.0001	+0.0000	-0.0001	-0.0002	-0.0003	-0.0004
11	-0.0004	-0.0004	-0.0003	-0.0002	-0.0001	-0.0000	+0.0001	+0.0002	+0.0003	+0.0003	+0.0004	+0.0003	+0.0003	+0.0002	+0.0001	+0.0000	-0.0001	-0.0002	-0.0003	-0.0003
12	-0.0003	-0.0003	-0.0003	-0.0002	-0.0001	-0.0000	+0.0001	+0.0002	+0.0002	+0.0003	+0.0003	+0.0003	+0.0002	+0.0002	+0.0001	+0.0000	-0.0001	-0.0002	-0.0002	-0.0003
13	-0.0003	-0.0003	-0.0002	-0.0002	-0.0001	-0.0000	+0.0001	+0.0002	+0.0002	+0.0002	+0.0003	+0.0002	+0.0002	+0.0002	+0.0001	+0.0000	-0.0001	-0.0001	-0.0002	-0.0002
14	-0.0002	-0.0002	-0.0002	-0.0001	-0.0001	-0.0000	+0.0001	+0.0001	+0.0002	+0.0002	+0.0002	+0.0002	+0.0002	+0.0001	+0.0001	+0.0000	-0.0001	-0.0001	-0.0002	-0.0002
15	-0.0002	-0.0002	-0.0002	-0.0001	-0.0001	-0.0000	+0.0001	+0.0001	+0.0002	+0.0002	+0.0002	+0.0002	+0.0002	+0.0001	+0.0001	+0.0000	-0.0001	-0.0001	-0.0001	-0.0002
16	-0.0002	-0.0002	-0.0002	-0.0001	-0.0001	-0.0000	+0.0001	+0.0001	+0.0001	+0.0002	+0.0002	+0.0002	+0.0001	+0.0001	+0.0001	+0.0000	-0.0000	-0.0001	-0.0001	-0.0002
17	-0.0002	-0.0002	-0.0001	-0.0001	-0.0001	-0.0000	+0.0000	+0.0001	+0.0001	+0.0001	+0.0002	+0.0001	+0.0001	+0.0001	+0.0000	+0.0000	-0.0000	-0.0001	-0.0001	-0.0001
18	-0.0001	-0.0001	-0.0001	-0.0001	-0.0000	-0.0000	+0.0000	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0000	+0.0000	-0.0000	-0.0001	-0.0001	-0.0001
19	-0.0001	-0.0001	-0.0001	-0.0001	-0.0000	-0.0000	+0.0000	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0000	+0.0000	-0.0000	-0.0001	-0.0001	-0.0001
20	-0.0001	-0.0001	-0.0001	-0.0001	-0.0000	-0.0000	+0.0000	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0000	+0.0000	-0.0000	-0.0001	-0.0001	-0.0001
21	-0.0001	-0.0001	-0.0001	-0.0001	-0.0000	-0.0000	+0.0000	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0000	+0.0000	-0.0000	-0.0001	-0.0001	-0.0001
22	-0.0001	-0.0001	-0.0001	-0.0001	-0.0000	-0.0000	+0.0000	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0000	+0.0000	-0.0000	-0.0001	-0.0001	-0.0001
23	-0.0001	-0.0001	-0.0001	-0.0001	-0.0000	-0.0000	+0.0000	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0000	+0.0000	-0.0000	-0.0000	-0.0001	-0.0001
24	-0.0001	-0.0001	-0.0001	-0.0000	-0.0000	-0.0000	+0.0000	+0.0000	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0000	+0.0000	+0.0000	-0.0000	-0.0000	-0.0001	-0.0001
25	-0.0001	-0.0001	-0.0001	-0.0000	-0.0000	-0.0000	+0.0000	+0.0000	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0000	+0.0000	+0.0000	-0.0000	-0.0000	-0.0001	-0.0001
26	-0.0001	-0.0001	-0.0001	-0.0000	-0.0000	-0.0000	+0.0000	+0.0000	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0000	+0.0000	+0.0000	-0.0000	-0.0000	-0.0001	-0.0001
27	-0.0001	-0.0001	-0.0001	-0.0000	-0.0000	-0.0000	+0.0000	+0.0000	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0000	+0.0000	+0.0000	-0.0000	-0.0000	-0.0000	-0.0001
28	-0.0001	-0.0001	-0.0000	-0.0000	-0.0000	-0.0000	+0.0000	+0.0000	+0.0000	+0.0001	+0.0001	+0.0001	+0.0000	+0.0000	+0.0000	+0.0000	-0.0000	-0.0000	-0.0000	-0.0001
29	-0.0001	-0.0001	-0.0000	-0.0000	-0.0000	-0.0000	+0.0000	+0.0000	+0.0000	+0.0001	+0.0001	+0.0001	+0.0000	+0.0000	+0.0000	+0.0000	-0.0000	-0.0000	-0.0000	-0.0001
30	-0.0001	-0.0001	-0.0000	-0.0000	-0.0000	-0.0000	+0.0000	+0.0000	+0.0000	+0.0000	+0.0001	+0.0000	+0.0000	+0.0000	+0.0000	+0.0000	-0.0000	-0.0000	-0.0000	-0.0000
31	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	+0.0000	+0.0000	+0.0000	+0.0000	+0.0000	+0.0000	+0.0000	+0.0000	+0.0000	+0.0000	-0.0000	-0.0000	-0.0000	-0.0000
32	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	+0.0000	+0.0000	+0.0000	+0.0000	+0.0000	+0.0000	+0.0000	+0.0000	+0.0000	+0.0000	-0.0000	-0.0000	-0.0000	-0.0000

AERIAL GAIN PER TIER

COLLINEAR λ/2 DIPOLES

P = -1·4294 Q = 0·4294 G = 1·0

INTER-TIER SPACING	NUMBER OF TIERS 2	3	4	5	6	8
0.25	0.5565	0.4338	0.3886	0.3689	0.3571	0.3420
0.3	0.5820	0.4779	0.4435	0.4266	0.4147	0.4013
0.35	0.6127	0.5280	0.5005	0.4835	0.4726	0.4604
0.4	0.6483	0.5821	0.5568	0.5405	0.5313	0.5195
0.45	0.6888	0.6373	0.6120	0.5982	0.5894	0.5786
0.5	0.7335	0.6918	0.6674	0.6558	0.6471	0.6373
0.55	0.7816	0.7443	0.7234	0.7123	0.7050	0.6960
0.6	0.8316	0.7955	0.7793	0.7685	0.7624	0.7543
0.65	0.8815	0.8463	0.8338	0.8248	0.8190	0.8122
0.7	0.9292	0.8976	0.8865	0.8804	0.8753	0.8698
0.75	0.9721	0.9490	0.9384	0.9341	0.9311	0.9264
0.8	1.0080	0.9983	0.9904	0.9865	0.9848	0.9828
0.85	1.0352	1.0414	1.0405	1.0386	1.0374	1.0371
0.9	1.0529	1.0737	1.0827	1.0867	1.0885	1.0898
0.95	1.0614	1.0915	1.1091	1.1203	1.1278	1.1368
1.0	1.0619	1.0942	1.1144	1.1284	1.1388	1.1533
1.05	1.0560	1.0840	1.1005	1.1111	1.1184	1.1272
1.1	1.0458	1.0654	1.0749	1.0798	1.0825	1.0852
1.15	1.0332	1.0435	1.0466	1.0477	1.0484	1.0499
1.2	1.0199	1.0223	1.0218	1.0217	1.0221	1.0227
1.25	1.0073	1.0044	1.0028	1.0026	1.0025	1.0020
1.3	0.9963	0.9909	0.9894	0.9887	0.9879	0.9871
1.35	0.9876	0.9818	0.9802	0.9788	0.9779	0.9769
1.4	0.9815	0.9764	0.9743	0.9725	0.9717	0.9704
1.45	0.9782	0.9738	0.9710	0.9695	0.9685	0.9672
1.5	0.9773	0.9734	0.9703	0.9690	0.9678	0.9665
1.55	0.9787	0.9746	0.9718	0.9704	0.9694	0.9682
1.6	0.9819	0.9772	0.9752	0.9736	0.9728	0.9716
1.65	0.9865	0.9814	0.9798	0.9784	0.9776	0.9766
1.7	0.9918	0.9870	0.9854	0.9845	0.9837	0.9829
1.75	0.9973	0.9938	0.9921	0.9915	0.9910	0.9903

INTER-TIER SPACING	NUMBER OF TIERS 8	10	12	16	20	24	32
0.7	0.8698	0.8663	0.8642	0.8614	0.8597	0.8586	0.8573
0.72	0.8925	0.8895	0.8875	0.8850	0.8835	0.8825	0.8813
0.74	0.9151	0.9126	0.9107	0.9085	0.9072	0.9063	0.9052
0.76	0.9377	0.9356	0.9339	0.9320	0.9309	0.9301	0.9292
0.78	0.9603	0.9583	0.9571	0.9555	0.9545	0.9539	0.9531
0.8	0.9828	0.9810	0.9801	0.9788	0.9780	0.9776	0.9769
0.82	1.0048	1.0036	1.0029	1.0020	1.0015	1.0012	1.0007
0.84	1.0264	1.0261	1.0255	1.0252	1.0249	1.0247	1.0245
0.86	1.0477	1.0481	1.0481	1.0481	1.0481	1.0481	1.0481
0.88	1.0688	1.0696	1.0704	1.0708	1.0712	1.0714	1.0717
0.9	1.0898	1.0908	1.0920	1.0934	1.0940	1.0945	1.0951
0.92	1.1103	1.1120	1.1132	1.1153	1.1166	1.1173	1.1184
0.94	1.1288	1.1323	1.1343	1.1367	1.1385	1.1398	1.1412
0.96	1.1435	1.1497	1.1535	1.1576	1.1599	1.1614	1.1636
0.98	1.1521	1.1608	1.1669	1.1745	1.1789	1.1817	1.1849
1.0	1.1533	1.1630	1.1699	1.1794	1.1856	1.1900	1.1958
1.02	1.1470	1.1556	1.1615	1.1690	1.1734	1.1762	1.1794
1.04	1.1349	1.1410	1.1448	1.1491	1.1514	1.1530	1.1553
1.06	1.1190	1.1228	1.1250	1.1278	1.1297	1.1310	1.1326
1.08	1.1019	1.1042	1.1058	1.1082	1.1097	1.1106	1.1118
1.1	1.0852	1.0870	1.0884	1.0903	1.0912	1.0920	1.0928
1.12	1.0699	1.0715	1.0726	1.0738	1.0746	1.0751	1.0757
1.14	1.0562	1.0575	1.0582	1.0590	1.0595	1.0599	1.0604
1.16	1.0439	1.0447	1.0451	1.0457	1.0460	1.0463	1.0466
1.18	1.0328	1.0331	1.0334	1.0337	1.0340	1.0341	1.0343
1.2	1.0227	1.0228	1.0230	1.0231	1.0232	1.0233	1.0233
1.22	1.0137	1.0136	1.0137	1.0137	1.0136	1.0136	1.0136
1.24	1.0056	1.0055	1.0054	1.0053	1.0052	1.0051	1.0051
1.26	0.9986	0.9984	0.9981	0.9979	0.9978	0.9977	0.9976
1.28	0.9925	0.9921	0.9918	0.9915	0.9913	0.9912	0.9910
1.3	0.9871	0.9866	0.9863	0.9859	0.9857	0.9855	0.9853

RELATIVE MUTUAL RESISTANCE

COLLINEAR DOUBLETS

P = −1·0 Q = 0·0

X\λ	·00	·05	·10	·15	·20	·25	·30	·35	·40	·45	·50	·55	·60	·65	·70	·75	·80	·85	·90	·95
0	+1.0000	+0.9902	+0.9611	+0.9139	+0.8507	+0.7740	+0.6869	+0.5928	+0.4953	+0.3979	+0.3040	+0.2165	+0.1379	+0.0701	+0.0144	−0.0287	−0.0592	−0.0778	−0.0857	−0.0844
1	−0.0760	−0.0623	−0.0455	−0.0273	−0.0097	+0.0062	+0.0191	+0.0285	+0.0340	+0.0356	+0.0338	+0.0291	+0.0223	+0.0142	+0.0058	−0.0023	−0.0092	−0.0146	−0.0181	−0.0195
2	−0.0190	−0.0168	−0.0132	−0.0087	−0.0038	+0.0011	+0.0054	+0.0088	+0.0112	+0.0123	+0.0122	+0.0109	+0.0087	+0.0058	+0.0026	−0.0006	−0.0035	−0.0059	−0.0076	−0.0085
3	−0.0084	−0.0076	−0.0062	−0.0042	−0.0019	+0.0004	+0.0025	+0.0042	+0.0055	+0.0062	+0.0062	+0.0057	+0.0046	+0.0032	+0.0015	−0.0002	−0.0018	−0.0032	−0.0042	−0.0047
4	−0.0047	−0.0043	−0.0036	−0.0025	−0.0012	+0.0002	+0.0014	+0.0025	+0.0033	+0.0037	+0.0038	+0.0035	+0.0028	+0.0020	+0.0010	−0.0001	−0.0011	−0.0020	−0.0026	−0.0030
5	−0.0030	−0.0028	−0.0023	−0.0016	−0.0008	+0.0001	+0.0009	+0.0016	+0.0022	+0.0025	+0.0025	+0.0023	+0.0019	+0.0013	+0.0007	−0.0001	−0.0008	−0.0014	−0.0018	−0.0021
6	−0.0021	−0.0020	−0.0016	−0.0011	−0.0006	+0.0000	+0.0006	+0.0011	+0.0015	+0.0018	+0.0018	+0.0017	+0.0014	+0.0010	+0.0005	−0.0000	−0.0005	−0.0010	−0.0013	−0.0015
7	−0.0016	−0.0014	−0.0012	−0.0008	−0.0004	+0.0000	+0.0005	+0.0009	+0.0011	+0.0013	+0.0014	+0.0013	+0.0010	+0.0007	+0.0004	−0.0000	−0.0004	−0.0007	−0.0010	−0.0012
8	−0.0012	−0.0011	−0.0009	−0.0007	−0.0003	+0.0000	+0.0004	+0.0007	+0.0009	+0.0010	+0.0011	+0.0010	+0.0008	+0.0006	+0.0003	−0.0000	−0.0003	−0.0006	−0.0008	−0.0009
9	−0.0009	−0.0009	−0.0007	−0.0005	−0.0003	+0.0000	+0.0003	+0.0005	+0.0007	+0.0008	+0.0008	+0.0008	+0.0007	+0.0005	+0.0002	−0.0000	−0.0003	−0.0005	−0.0006	−0.0007
10	−0.0008	−0.0007	−0.0006	−0.0004	−0.0002	+0.0000	+0.0002	+0.0004	+0.0006	+0.0007	+0.0007	+0.0006	+0.0005	+0.0004	+0.0002	−0.0000	−0.0002	−0.0004	−0.0005	−0.0006
11	−0.0006	−0.0006	−0.0005	−0.0004	−0.0002	+0.0000	+0.0002	+0.0004	+0.0005	+0.0006	+0.0006	+0.0005	+0.0005	+0.0003	+0.0002	−0.0000	−0.0002	−0.0003	−0.0004	−0.0005
12	−0.0005	−0.0005	−0.0004	−0.0003	−0.0002	+0.0000	+0.0002	+0.0003	+0.0004	+0.0005	+0.0005	+0.0005	+0.0004	+0.0003	+0.0001	−0.0000	−0.0001	−0.0003	−0.0004	−0.0004
13	−0.0004	−0.0004	−0.0004	−0.0003	−0.0001	+0.0000	+0.0001	+0.0003	+0.0003	+0.0004	+0.0004	+0.0004	+0.0003	+0.0002	+0.0001	−0.0000	−0.0001	−0.0002	−0.0003	−0.0004
14	−0.0004	−0.0004	−0.0003	−0.0002	−0.0001	+0.0000	+0.0001	+0.0002	+0.0003	+0.0003	+0.0004	+0.0003	+0.0003	+0.0002	+0.0001	−0.0000	−0.0001	−0.0002	−0.0003	−0.0003
15	−0.0003	−0.0003	−0.0003	−0.0002	−0.0001	+0.0000	+0.0001	+0.0002	+0.0003	+0.0003	+0.0003	+0.0003	+0.0003	+0.0002	+0.0001	−0.0000	−0.0001	−0.0002	−0.0002	−0.0003
16	−0.0003	−0.0003	−0.0002	−0.0002	−0.0001	+0.0000	+0.0001	+0.0002	+0.0002	+0.0003	+0.0003	+0.0003	+0.0002	+0.0002	+0.0001	−0.0000	−0.0001	−0.0002	−0.0002	−0.0003
17	−0.0003	−0.0002	−0.0002	−0.0001	−0.0001	+0.0000	+0.0001	+0.0002	+0.0002	+0.0002	+0.0002	+0.0002	+0.0002	+0.0001	+0.0001	−0.0000	−0.0001	−0.0001	−0.0002	−0.0002
18	−0.0002	−0.0002	−0.0002	−0.0001	−0.0001	+0.0000	+0.0001	+0.0001	+0.0002	+0.0002	+0.0002	+0.0002	+0.0002	+0.0001	+0.0001	−0.0000	−0.0001	−0.0001	−0.0002	−0.0002
19	−0.0002	−0.0002	−0.0002	−0.0001	−0.0001	+0.0000	+0.0001	+0.0001	+0.0002	+0.0002	+0.0002	+0.0002	+0.0002	+0.0001	+0.0001	−0.0000	−0.0001	−0.0001	−0.0002	−0.0002
20	−0.0002	−0.0002	−0.0002	−0.0001	−0.0001	+0.0000	+0.0001	+0.0001	+0.0001	+0.0002	+0.0002	+0.0002	+0.0001	+0.0001	+0.0001	−0.0000	−0.0001	−0.0001	−0.0001	−0.0002
21	−0.0002	−0.0002	−0.0001	−0.0001	−0.0001	+0.0000	+0.0001	+0.0001	+0.0001	+0.0002	+0.0002	+0.0002	+0.0001	+0.0001	+0.0000	−0.0000	−0.0001	−0.0001	−0.0001	−0.0002
22	−0.0002	−0.0001	−0.0001	−0.0001	−0.0000	+0.0000	+0.0000	+0.0001	+0.0001	+0.0001	+0.0002	+0.0001	+0.0001	+0.0001	+0.0000	−0.0000	−0.0000	−0.0001	−0.0001	−0.0001
23	−0.0001	−0.0001	−0.0001	−0.0001	−0.0000	+0.0000	+0.0000	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0000	−0.0000	−0.0000	−0.0001	−0.0001	−0.0001
24	−0.0001	−0.0001	−0.0001	−0.0001	−0.0000	+0.0000	+0.0000	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0000	−0.0000	−0.0000	−0.0001	−0.0001	−0.0001
25	−0.0001	−0.0001	−0.0001	−0.0001	−0.0000	+0.0000	+0.0000	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0000	−0.0000	−0.0000	−0.0001	−0.0001	−0.0001
26	−0.0001	−0.0001	−0.0001	−0.0001	−0.0000	+0.0000	+0.0000	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0000	−0.0000	−0.0000	−0.0001	−0.0001	−0.0001
27	−0.0001	−0.0001	−0.0001	−0.0001	−0.0000	+0.0000	+0.0000	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0000	−0.0000	−0.0000	−0.0001	−0.0001	−0.0001
28	−0.0001	−0.0001	−0.0001	−0.0001	−0.0000	+0.0000	+0.0000	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0000	−0.0000	−0.0000	−0.0001	−0.0001	−0.0001
29	−0.0001	−0.0001	−0.0001	−0.0001	−0.0000	+0.0000	+0.0000	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0000	−0.0000	−0.0000	−0.0001	−0.0001	−0.0001
30	−0.0001	−0.0001	−0.0001	−0.0000	−0.0000	+0.0000	+0.0000	+0.0000	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0000	+0.0000	−0.0000	−0.0000	−0.0000	−0.0001	−0.0001
31	−0.0001	−0.0001	−0.0001	−0.0000	−0.0000	+0.0000	+0.0000	+0.0000	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0000	+0.0000	−0.0000	−0.0000	−0.0000	−0.0001	−0.0001
32	−0.0001	−0.0001	−0.0001	−0.0000	−0.0000	+0.0000	+0.0000	+0.0000	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0000	+0.0000	−0.0000	−0.0000	−0.0000	−0.0001	−0.0001

AERIAL GAIN PER TIER

COLLINEAR DOUBLETS

P = −1·0   Q = 0·0   G = 0·9141

INTER-TIER SPACING	NUMBER OF TIERS 2	3	4	5	6	8
0·25	0·5153	0·4091	0·3730	0·3585	0·3492	0·3361
0·3	0·5419	0·4553	0·4301	0·4170	0·4067	0·3958
0·35	0·5739	0·5078	0·4882	0·4738	0·4648	0·4548
0·4	0·6113	0·5639	0·5444	0·5306	0·5237	0·5139
0·45	0·6539	0·6204	0·5992	0·5886	0·5816	0·5730
0·5	0·7010	0·6748	0·6544	0·6462	0·6390	0·6315
0·55	0·7515	0·7265	0·7106	0·7023	0·6969	0·6901
0·6	0·8034	0·7764	0·7665	0·7579	0·7540	0·7480
0·65	0·8542	0·8264	0·8202	0·8140	0·8099	0·8056
0·7	0·9012	0·8774	0·8715	0·8691	0·8658	0·8628
0·75	0·9411	0·9287	0·9221	0·9214	0·9209	0·9186
0·8	0·9716	0·9766	0·9734	0·9722	0·9731	0·9742
0·85	0·9912	1·0155	1·0218	1·0231	1·0240	1·0269
0·9	0·9997	1·0392	1·0585	1·0681	1·0730	1·0777
0·95	0·9984	1·0443	1·0725	1·0912	1·1040	1·1197
1·0	0·9893	1·0317	1·0595	1·0793	1·0942	1·1155
1·05	0·9749	1·0066	1·0257	1·0380	1·0464	1·0564
1·1	0·9577	0·9757	0·9837	0·9872	0·9886	0·9895
1·15	0·9398	0·9452	0·9449	0·9436	0·9427	0·9426
1·2	0·9230	0·9191	0·9150	0·9130	0·9123	0·9114
1·25	0·9085	0·8994	0·8950	0·8935	0·8924	0·8906
1·3	0·8970	0·8864	0·8829	0·8812	0·8795	0·8777
1·35	0·8888	0·8792	0·8763	0·8738	0·8722	0·8704
1·4	0·8841	0·8765	0·8732	0·8706	0·8694	0·8674
1·45	0·8827	0·8769	0·8731	0·8710	0·8696	0·8679
1·5	0·8843	0·8795	0·8755	0·8739	0·8724	0·8708
1·55	0·8883	0·8835	0·8803	0·8786	0·8774	0·8760
1·6	0·8942	0·8889	0·8867	0·8849	0·8840	0·8827
1·65	0·9013	0·8957	0·8942	0·8928	0·8919	0·8909
1·7	0·9089	0·9038	0·9024	0·9017	0·9009	0·9002
1·75	0·9162	0·9131	0·9115	0·9111	0·9109	0·9103

INTER-TIER SPACING	NUMBER OF TIERS 8	10	12	16	20	24	32
0·7	0·8628	0·8606	0·8595	0·8579	0·8569	0·8563	0·8555
0·72	0·8852	0·8837	0·8827	0·8814	0·8806	0·8801	0·8795
0·74	0·9075	0·9066	0·9057	0·9048	0·9042	0·9038	0·9034
0·76	0·9298	0·9293	0·9287	0·9281	0·9278	0·9275	0·9272
0·78	0·9521	0·9517	0·9517	0·9514	0·9512	0·9511	0·9510
0·8	0·9742	0·9740	0·9744	0·9745	0·9746	0·9747	0·9748
0·82	0·9958	0·9963	0·9967	0·9974	0·9979	0·9981	0·9985
0·84	1·0167	1·0184	1·0190	1·0203	1·0210	1·0215	1·0220
0·86	1·0371	1·0399	1·0412	1·0429	1·0439	1·0447	1·0455
0·88	1·0574	1·0605	1·0629	1·0651	1·0667	1·0676	1·0689
0·9	1·0777	1·0808	1·0836	1·0872	1·0890	1·0904	1·0920
0·92	1·0971	1·1011	1·1039	1·1084	1·1111	1·1126	1·1149
0·94	1·1136	1·1201	1·1239	1·1286	1·1320	1·1345	1·1372
0·96	1·1239	1·1345	1·1411	1·1483	1·1522	1·1549	1·1587
0·98	1·1250	1·1390	1·1488	1·1613	1·1686	1·1732	1·1785
1·0	1·1155	1·1300	1·1406	1·1552	1·1649	1·1718	1·1811
1·02	1·0963	1·1080	1·1161	1·1265	1·1326	1·1364	1·1407
1·04	1·0705	1·0778	1·0823	1·0870	1·0896	1·0913	1·0939
1·06	1·0420	1·0456	1·0475	1·0499	1·0517	1·0531	1·0545
1·08	1·0144	1·0158	1·0168	1·0188	1·0199	1·0205	1·0215
1·1	0·9895	0·9903	0·9912	0·9924	0·9929	0·9933	0·9938
1·12	0·9663	0·9689	0·9695	0·9698	0·9701	0·9703	0·9705
1·14	0·9504	0·9508	0·9509	0·9508	0·9509	0·9509	0·9509
1·16	0·9354	0·9352	0·9349	0·9348	0·9346	0·9345	0·9344
1·18	0·9225	0·9219	0·9215	0·9211	0·9208	0·9207	0·9204
1·2	0·9114	0·9106	0·9102	0·9096	0·9092	0·9090	0·9087
1·22	0·9020	0·9011	0·9006	0·8999	0·8995	0·8992	0·8988
1·24	0·8940	0·8932	0·8925	0·8917	0·8913	0·8910	0·8906
1·26	0·8874	0·8865	0·8858	0·8850	0·8845	0·8841	0·8837
1·28	0·8821	0·8810	0·8803	0·8794	0·8789	0·8786	0·8781
1·3	0·8777	0·8765	0·8759	0·8749	0·8744	0·8740	0·8736

RELATIVE MUTUAL RESISTANCE

P = 0·0 Q = -1·0

X/λ	.00	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75	.80	.85	.90	.95
0	+1.0000	+0.9883	+0.9537	+0.8978	+0.8232	+0.7331	+0.6316	+0.5229	+0.4118	+0.3022	+0.1988	+0.1048	+0.0231	-0.0440	-0.0952	-0.1304	-0.1501	-0.1554	-0.1485	-0.1316
1	-0.1074	-0.0788	-0.0485	-0.0189	+0.0078	+0.0300	+0.0465	+0.0568	+0.0608	+0.0591	+0.0525	+0.0421	+0.0291	+0.0151	+0.0013	-0.0111	-0.0212	-0.0284	-0.0323	-0.0329
2	-0.0305	-0.0255	-0.0186	-0.0107	-0.0025	+0.0053	+0.0119	+0.0168	+0.0199	+0.0208	+0.0198	+0.0170	+0.0128	+0.0078	+0.0024	-0.0029	-0.0075	-0.0111	-0.0134	-0.0143
3	-0.0138	-0.0121	-0.0093	-0.0058	-0.0020	+0.0018	+0.0051	+0.0078	+0.0096	+0.0104	+0.0102	+0.0090	+0.0071	+0.0045	+0.0017	-0.0011	-0.0037	-0.0058	-0.0073	-0.0079
4	-0.0078	-0.0070	-0.0055	-0.0036	-0.0014	+0.0008	+0.0028	+0.0045	+0.0057	+0.0062	+0.0062	+0.0056	+0.0044	+0.0029	+0.0012	-0.0006	-0.0022	-0.0036	-0.0045	-0.0050
5	-0.0050	-0.0046	-0.0036	-0.0024	-0.0010	+0.0004	+0.0018	+0.0029	+0.0037	+0.0041	+0.0042	+0.0038	+0.0030	+0.0021	+0.0009	-0.0003	-0.0015	-0.0024	-0.0031	-0.0035
6	-0.0035	-0.0032	-0.0026	-0.0018	-0.0008	+0.0002	+0.0012	+0.0020	+0.0026	+0.0030	+0.0030	+0.0027	+0.0022	+0.0015	+0.0007	-0.0002	-0.0010	-0.0017	-0.0023	-0.0025
7	-0.0026	-0.0024	-0.0019	-0.0013	-0.0006	+0.0002	+0.0009	+0.0015	+0.0020	+0.0022	+0.0022	+0.0021	+0.0017	+0.0012	+0.0005	-0.0001	-0.0008	-0.0013	-0.0017	-0.0019
8	-0.0020	-0.0018	-0.0015	-0.0010	-0.0005	+0.0001	+0.0007	+0.0011	+0.0015	+0.0017	+0.0017	+0.0016	+0.0013	+0.0009	+0.0004	-0.0001	-0.0006	-0.0010	-0.0013	-0.0015
9	-0.0016	-0.0014	-0.0012	-0.0008	-0.0004	+0.0001	+0.0005	+0.0009	+0.0012	+0.0014	+0.0014	+0.0013	+0.0011	+0.0007	+0.0004	-0.0001	-0.0005	-0.0008	-0.0011	-0.0012
10	-0.0013	-0.0012	-0.0010	-0.0007	-0.0003	+0.0001	+0.0004	+0.0007	+0.0010	+0.0011	+0.0011	+0.0011	+0.0009	+0.0006	+0.0003	-0.0000	-0.0004	-0.0007	-0.0009	-0.0010
11	-0.0010	-0.0010	-0.0008	-0.0006	-0.0003	+0.0000	+0.0003	+0.0005	+0.0008	+0.0009	+0.0010	+0.0009	+0.0007	+0.0005	+0.0002	-0.0000	-0.0003	-0.0006	-0.0007	-0.0009
12	-0.0009	-0.0008	-0.0007	-0.0005	-0.0002	+0.0000	+0.0003	+0.0005	+0.0007	+0.0008	+0.0008	+0.0008	+0.0006	+0.0004	+0.0002	-0.0000	-0.0003	-0.0005	-0.0006	-0.0007
13	-0.0007	-0.0007	-0.0006	-0.0004	-0.0002	+0.0000	+0.0002	+0.0004	+0.0006	+0.0007	+0.0007	+0.0006	+0.0005	+0.0004	+0.0002	-0.0000	-0.0002	-0.0004	-0.0005	-0.0006
14	-0.0006	-0.0006	-0.0005	-0.0004	-0.0002	+0.0000	+0.0002	+0.0004	+0.0005	+0.0006	+0.0006	+0.0006	+0.0005	+0.0003	+0.0002	-0.0000	-0.0002	-0.0004	-0.0005	-0.0005
15	-0.0006	-0.0005	-0.0004	-0.0003	-0.0002	+0.0000	+0.0002	+0.0003	+0.0004	+0.0005	+0.0005	+0.0005	+0.0004	+0.0003	+0.0001	-0.0000	-0.0002	-0.0003	-0.0004	-0.0005
16	-0.0005	-0.0005	-0.0004	-0.0003	-0.0001	+0.0000	+0.0002	+0.0003	+0.0004	+0.0004	+0.0005	+0.0004	+0.0004	+0.0003	+0.0001	-0.0000	-0.0002	-0.0003	-0.0004	-0.0004
17	-0.0004	-0.0004	-0.0003	-0.0002	-0.0001	+0.0000	+0.0001	+0.0003	+0.0003	+0.0004	+0.0004	+0.0004	+0.0003	+0.0002	+0.0001	-0.0000	-0.0001	-0.0002	-0.0003	-0.0004
18	-0.0004	-0.0004	-0.0003	-0.0002	-0.0001	+0.0000	+0.0001	+0.0002	+0.0003	+0.0004	+0.0004	+0.0003	+0.0003	+0.0002	+0.0001	-0.0000	-0.0001	-0.0002	-0.0003	-0.0003
19	-0.0004	-0.0003	-0.0003	-0.0002	-0.0001	+0.0000	+0.0001	+0.0002	+0.0003	+0.0003	+0.0003	+0.0003	+0.0003	+0.0002	+0.0001	-0.0000	-0.0001	-0.0002	-0.0003	-0.0003
20	-0.0003	-0.0003	-0.0002	-0.0002	-0.0001	+0.0000	+0.0001	+0.0002	+0.0003	+0.0003	+0.0003	+0.0003	+0.0002	+0.0002	+0.0001	-0.0000	-0.0001	-0.0002	-0.0002	-0.0003
21	-0.0003	-0.0003	-0.0002	-0.0002	-0.0001	+0.0000	+0.0001	+0.0002	+0.0002	+0.0003	+0.0003	+0.0003	+0.0002	+0.0002	+0.0001	-0.0000	-0.0001	-0.0002	-0.0002	-0.0003
22	-0.0003	-0.0002	-0.0002	-0.0001	-0.0001	+0.0000	+0.0001	+0.0002	+0.0002	+0.0002	+0.0003	+0.0002	+0.0002	+0.0001	+0.0001	-0.0000	-0.0001	-0.0001	-0.0002	-0.0002
23	-0.0002	-0.0002	-0.0002	-0.0001	-0.0001	+0.0000	+0.0001	+0.0001	+0.0002	+0.0002	+0.0002	+0.0002	+0.0002	+0.0001	+0.0001	-0.0000	-0.0001	-0.0001	-0.0002	-0.0002
24	-0.0002	-0.0002	-0.0002	-0.0001	-0.0001	+0.0000	+0.0001	+0.0001	+0.0002	+0.0002	+0.0002	+0.0002	+0.0002	+0.0001	+0.0001	-0.0000	-0.0001	-0.0001	-0.0002	-0.0002
25	-0.0002	-0.0002	-0.0002	-0.0001	-0.0001	+0.0000	+0.0001	+0.0001	+0.0002	+0.0002	+0.0002	+0.0002	+0.0002	+0.0001	+0.0001	-0.0000	-0.0001	-0.0001	-0.0002	-0.0002
26	-0.0002	-0.0002	-0.0001	-0.0001	-0.0001	+0.0000	+0.0001	+0.0001	+0.0001	+0.0002	+0.0002	+0.0002	+0.0001	+0.0001	+0.0001	-0.0000	-0.0001	-0.0001	-0.0001	-0.0002
27	-0.0002	-0.0002	-0.0001	-0.0001	-0.0001	+0.0000	+0.0001	+0.0001	+0.0001	+0.0002	+0.0002	+0.0002	+0.0001	+0.0001	+0.0000	-0.0000	-0.0001	-0.0001	-0.0001	-0.0002
28	-0.0002	-0.0002	-0.0001	-0.0001	-0.0000	+0.0000	+0.0001	+0.0001	+0.0001	+0.0001	+0.0002	+0.0001	+0.0001	+0.0001	+0.0000	-0.0000	-0.0000	-0.0001	-0.0001	-0.0001
29	-0.0002	-0.0001	-0.0001	-0.0001	-0.0000	+0.0000	+0.0000	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0000	-0.0000	-0.0000	-0.0001	-0.0001	-0.0001
30	-0.0001	-0.0001	-0.0001	-0.0001	-0.0000	+0.0000	+0.0000	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0000	-0.0000	-0.0000	-0.0001	-0.0001	-0.0001
31	-0.0001	-0.0001	-0.0001	-0.0001	-0.0000	+0.0000	+0.0000	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0000	-0.0000	-0.0000	-0.0001	-0.0001	-0.0001
32	-0.0001	-0.0001	-0.0001	-0.0001	-0.0000	+0.0000	+0.0000	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0001	+0.0000	-0.0000	-0.0000	-0.0001	-0.0001	-0.0001

AERIAL GAIN PER TIER

P = 0·0   Q = -1·0   G = 0·7618

INTER-TIER SPACING	NUMBER OF TIERS 2	3	4	5	6	8
0.25	0.4395	0.3610	0.3411	0.3365	0.3320	0.3233
0.3	0.4669	0.4101	0.4017	0.3962	0.3891	0.3835
0.35	0.5002	0.4663	0.4618	0.4524	0.4474	0.4423
0.4	0.5396	0.5258	0.5178	0.5091	0.5068	0.5014
0.45	0.5850	0.5842	0.5714	0.5675	0.5643	0.5603
0.5	0.6355	0.6384	0.6261	0.6251	0.6210	0.6183
0.55	0.6896	0.6880	0.6826	0.6799	0.6788	0.6767
0.6	0.7446	0.7353	0.7383	0.7344	0.7351	0.7337
0.65	0.7968	0.7834	0.7902	0.7900	0.7895	0.7906
0.7	0.8420	0.8338	0.8383	0.8439	0.8444	0.8468
0.75	0.8760	0.8847	0.8863	0.8931	0.8980	0.9009
0.8	0.8963	0.9297	0.9359	0.9405	0.9467	0.9550
0.85	0.9020	0.9598	0.9808	0.9889	0.9940	1.0040
0.9	0.8946	0.9668	1.0060	1.0271	1.0387	1.0505
0.95	0.8772	0.9486	0.9960	1.0289	1.0523	1.0819
1.0	0.8534	0.9107	0.9504	0.9799	1.0028	1.0363
1.05	0.8269	0.8632	0.8855	0.9001	0.9099	0.9214
1.1	0.8006	0.8158	0.8214	0.8228	0.8224	0.8209
1.15	0.7764	0.7752	0.7704	0.7662	0.7636	0.7614
1.2	0.7559	0.7442	0.7359	0.7317	0.7297	0.7272
1.25	0.7396	0.7233	0.7159	0.7128	0.7107	0.7074
1.3	0.7279	0.7116	0.7061	0.7031	0.7004	0.6976
1.35	0.7208	0.7071	0.7027	0.6992	0.6968	0.6942
1.4	0.7181	0.7079	0.7034	0.6999	0.6981	0.6956
1.45	0.7192	0.7120	0.7070	0.7043	0.7026	0.7004
1.5	0.7238	0.7181	0.7133	0.7113	0.7095	0.7076
1.55	0.7310	0.7256	0.7219	0.7199	0.7186	0.7169
1.6	0.7402	0.7342	0.7321	0.7300	0.7291	0.7277
1.65	0.7504	0.7442	0.7430	0.7416	0.7406	0.7397
1.7	0.7608	0.7556	0.7544	0.7539	0.7532	0.7526
1.75	0.7703	0.7679	0.7665	0.7665	0.7665	0.7661

INTER-TIER SPACING	NUMBER OF TIERS 8	10	12	16	20	24	32
0.7	0.8468	0.8477	0.8488	0.8498	0.8505	0.8510	0.8515
0.72	0.8685	0.8704	0.8716	0.8731	0.8740	0.8746	0.8753
0.74	0.8901	0.8929	0.8942	0.8961	0.8973	0.8981	0.8990
0.76	0.9118	0.9151	0.9167	0.9191	0.9206	0.9215	0.9227
0.78	0.9336	0.9367	0.9392	0.9420	0.9437	0.9449	0.9463
0.8	0.9550	0.9581	0.9613	0.9646	0.9666	0.9681	0.9698
0.82	0.9754	0.9797	0.9828	0.9870	0.9895	0.9911	0.9932
0.84	0.9947	1.0010	1.0042	1.0093	1.0120	1.0140	1.0164
0.86	1.0132	1.0211	1.0256	1.0309	1.0343	1.0366	1.0395
0.88	1.0318	1.0399	1.0460	1.0521	1.0563	1.0589	1.0623
0.9	1.0505	1.0581	1.0647	1.0732	1.0775	1.0808	1.0848
0.92	1.0677	1.0765	1.0827	1.0924	1.0984	1.1019	1.1068
0.94	1.0796	1.0928	1.1005	1.1102	1.1172	1.1222	1.1278
0.96	1.0807	1.1006	1.1131	1.1271	1.1346	1.1399	1.1475
0.98	1.0666	1.0912	1.1087	1.1316	1.1453	1.1540	1.1639
1.0	1.0363	1.0600	1.0776	1.1024	1.1192	1.1315	1.1481
1.02	0.9938	1.0110	1.0231	1.0386	1.0477	1.0533	1.0597
1.04	0.9456	0.9547	0.9601	0.9657	0.9684	0.9704	0.9735
1.06	0.8982	0.9012	0.9026	0.9044	0.9061	0.9073	0.9085
1.08	0.8560	0.8561	0.8564	0.8575	0.8582	0.8585	0.8590
1.1	0.8209	0.8203	0.8205	0.8207	0.8206	0.8206	0.8206
1.12	0.7929	0.7923	0.7921	0.7913	0.7911	0.7908	0.7905
1.14	0.7707	0.7700	0.7692	0.7681	0.7675	0.7672	0.7667
1.16	0.7531	0.7518	0.7507	0.7496	0.7488	0.7483	0.7477
1.18	0.7388	0.7371	0.7359	0.7346	0.7339	0.7333	0.7326
1.2	0.7272	0.7253	0.7242	0.7228	0.7219	0.7214	0.7207
1.22	0.7178	0.7160	0.7149	0.7134	0.7125	0.7119	0.7112
1.24	0.7104	0.7087	0.7075	0.7060	0.7051	0.7046	0.7038
1.26	0.7047	0.7031	0.7018	0.7004	0.6995	0.6989	0.6982
1.28	0.7006	0.6988	0.6977	0.6962	0.6953	0.6947	0.6940
1.3	0.6976	0.6958	0.6947	0.6932	0.6924	0.6918	0.6911

RELATIVE MUTUAL RESISTANCE

P = 3·0 Q = -4·0

X \	·00	·05	·10	·15	·20	·25	·30	·35	·40	·45	·50	·55	·60	·65	·70	·75	·80	·85	·90	·95
0	+1.0000	+0.9852	+0.9415	+0.8710	+0.7773	+0.6650	+0.5393	+0.4064	+0.2721	+0.1426	+0.0231	-0.0818	-0.1683	-0.2341	-0.2780	-0.3000	-0.3016	-0.2850	-0.2532	-0.2101
1	-0.1598	-0.1062	-0.0534	-0.0048	+0.0369	+0.0696	+0.0920	+0.1039	+0.1057	+0.0983	+0.0837	+0.0637	+0.0406	+0.0166	-0.0061	-0.0258	-0.0412	-0.0514	-0.0560	-0.0552
2	-0.0496	-0.0400	-0.0278	-0.0141	-0.0003	+0.0122	+0.0227	+0.0302	+0.0343	+0.0350	+0.0325	+0.0271	+0.0197	+0.0110	+0.0019	-0.0067	-0.0141	-0.0197	-0.0231	-0.0241
3	-0.0228	-0.0195	-0.0146	-0.0086	-0.0021	+0.0041	+0.0096	+0.0138	+0.0166	+0.0176	+0.0169	+0.0147	+0.0112	+0.0068	+0.0020	-0.0027	-0.0069	-0.0102	-0.0124	-0.0134
4	-0.0130	-0.0114	-0.0088	-0.0055	-0.0018	+0.0018	+0.0052	+0.0079	+0.0097	+0.0105	+0.0103	+0.0091	+0.0071	+0.0045	+0.0016	-0.0013	-0.0040	-0.0062	-0.0077	-0.0085
5	-0.0084	-0.0075	-0.0059	-0.0038	-0.0014	+0.0010	+0.0032	+0.0050	+0.0063	+0.0070	+0.0069	+0.0062	+0.0049	+0.0032	+0.0013	-0.0007	-0.0026	-0.0042	-0.0053	-0.0058
6	-0.0058	-0.0053	-0.0042	-0.0028	-0.0011	+0.0006	+0.0022	+0.0035	+0.0045	+0.0050	+0.0050	+0.0045	+0.0036	+0.0024	+0.0010	-0.0005	-0.0018	-0.0030	-0.0038	-0.0043
7	-0.0043	-0.0039	-0.0031	-0.0021	-0.0009	+0.0004	+0.0016	+0.0026	+0.0033	+0.0037	+0.0037	+0.0034	+0.0028	+0.0019	+0.0008	-0.0003	-0.0014	-0.0022	-0.0029	-0.0033
8	-0.0033	-0.0030	-0.0024	-0.0017	-0.0007	+0.0003	+0.0012	+0.0020	+0.0026	+0.0029	+0.0029	+0.0027	+0.0022	+0.0015	+0.0007	-0.0002	-0.0010	-0.0017	-0.0023	-0.0026
9	-0.0026	-0.0024	-0.0019	-0.0013	-0.0006	+0.0002	+0.0009	+0.0016	+0.0020	+0.0023	+0.0023	+0.0021	+0.0018	+0.0012	+0.0005	-0.0002	-0.0008	-0.0014	-0.0018	-0.0021
10	-0.0021	-0.0019	-0.0016	-0.0011	-0.0005	+0.0001	+0.0007	+0.0013	+0.0016	+0.0019	+0.0019	+0.0018	+0.0014	+0.0010	+0.0005	-0.0001	-0.0007	-0.0011	-0.0015	-0.0017
11	-0.0017	-0.0016	-0.0013	-0.0009	-0.0004	+0.0001	+0.0006	+0.0010	+0.0014	+0.0016	+0.0016	+0.0015	+0.0012	+0.0008	+0.0004	-0.0001	-0.0005	-0.0010	-0.0013	-0.0014
12	-0.0015	-0.0014	-0.0011	-0.0008	-0.0004	+0.0001	+0.0005	+0.0009	+0.0012	+0.0013	+0.0013	+0.0013	+0.0010	+0.0007	+0.0003	-0.0001	-0.0005	-0.0008	-0.0011	-0.0012
13	-0.0012	-0.0012	-0.0010	-0.0007	-0.0003	+0.0001	+0.0004	+0.0007	+0.0010	+0.0011	+0.0012	+0.0011	+0.0009	+0.0006	+0.0003	-0.0001	-0.0004	-0.0007	-0.0009	-0.0010
14	-0.0011	-0.0010	-0.0008	-0.0006	-0.0003	+0.0000	+0.0004	+0.0006	+0.0009	+0.0010	+0.0010	+0.0009	+0.0008	+0.0005	+0.0003	-0.0000	-0.0003	-0.0006	-0.0008	-0.0009
15	-0.0009	-0.0009	-0.0007	-0.0005	-0.0002	+0.0000	+0.0003	+0.0006	+0.0007	+0.0009	+0.0009	+0.0008	+0.0007	+0.0005	+0.0002	-0.0000	-0.0003	-0.0005	-0.0007	-0.0008
16	-0.0008	-0.0008	-0.0006	-0.0004	-0.0002	+0.0000	+0.0003	+0.0005	+0.0007	+0.0008	+0.0008	+0.0007	+0.0006	+0.0004	+0.0002	-0.0000	-0.0003	-0.0005	-0.0006	-0.0007
17	-0.0007	-0.0007	-0.0006	-0.0004	-0.0002	+0.0000	+0.0002	+0.0004	+0.0006	+0.0007	+0.0007	+0.0006	+0.0005	+0.0004	+0.0002	-0.0000	-0.0003	-0.0004	-0.0005	-0.0006
18	-0.0007	-0.0006	-0.0005	-0.0004	-0.0002	+0.0000	+0.0002	+0.0004	+0.0005	+0.0006	+0.0006	+0.0006	+0.0005	+0.0003	+0.0002	-0.0000	-0.0002	-0.0004	-0.0005	-0.0006
19	-0.0006	-0.0005	-0.0005	-0.0003	-0.0002	+0.0000	+0.0002	+0.0003	+0.0005	+0.0005	+0.0006	+0.0005	+0.0004	+0.0003	+0.0002	-0.0000	-0.0002	-0.0003	-0.0004	-0.0005
20	-0.0005	-0.0005	-0.0004	-0.0003	-0.0001	+0.0000	+0.0002	+0.0003	+0.0004	+0.0005	+0.0005	+0.0005	+0.0004	+0.0003	+0.0001	-0.0000	-0.0002	-0.0003	-0.0004	-0.0005
21	-0.0005	-0.0004	-0.0004	-0.0003	-0.0001	+0.0000	+0.0002	+0.0003	+0.0004	+0.0004	+0.0005	+0.0004	+0.0004	+0.0003	+0.0001	-0.0000	-0.0002	-0.0003	-0.0004	-0.0004
22	-0.0004	-0.0004	-0.0003	-0.0002	-0.0001	+0.0000	+0.0001	+0.0003	+0.0003	+0.0004	+0.0004	+0.0004	+0.0003	+0.0002	+0.0001	-0.0000	-0.0001	-0.0002	-0.0003	-0.0004
23	-0.0004	-0.0004	-0.0003	-0.0002	-0.0001	+0.0000	+0.0001	+0.0002	+0.0003	+0.0004	+0.0004	+0.0004	+0.0003	+0.0002	+0.0001	-0.0000	-0.0001	-0.0002	-0.0003	-0.0004
24	-0.0004	-0.0003	-0.0003	-0.0002	-0.0001	+0.0000	+0.0001	+0.0002	+0.0003	+0.0003	+0.0004	+0.0003	+0.0003	+0.0002	+0.0001	-0.0000	-0.0001	-0.0002	-0.0003	-0.0003
25	-0.0003	-0.0003	-0.0003	-0.0002	-0.0001	+0.0000	+0.0001	+0.0002	+0.0003	+0.0003	+0.0003	+0.0003	+0.0003	+0.0002	+0.0001	-0.0000	-0.0001	-0.0002	-0.0003	-0.0003
26	-0.0003	-0.0003	-0.0002	-0.0002	-0.0001	+0.0000	+0.0001	+0.0002	+0.0002	+0.0003	+0.0003	+0.0003	+0.0002	+0.0002	+0.0001	-0.0000	-0.0001	-0.0002	-0.0002	-0.0003
27	-0.0003	-0.0003	-0.0002	-0.0002	-0.0001	+0.0000	+0.0001	+0.0002	+0.0002	+0.0003	+0.0003	+0.0003	+0.0002	+0.0002	+0.0001	-0.0000	-0.0001	-0.0002	-0.0002	-0.0003
28	-0.0003	-0.0003	-0.0002	-0.0002	-0.0001	+0.0000	+0.0001	+0.0002	+0.0002	+0.0003	+0.0003	+0.0002	+0.0002	+0.0001	+0.0001	-0.0000	-0.0001	-0.0002	-0.0002	-0.0002
29	-0.0003	-0.0002	-0.0002	-0.0001	-0.0001	+0.0000	+0.0001	+0.0001	+0.0002	+0.0002	+0.0002	+0.0002	+0.0002	+0.0001	+0.0001	-0.0000	-0.0001	-0.0001	-0.0002	-0.0002
30	-0.0002	-0.0002	-0.0002	-0.0001	-0.0001	+0.0000	+0.0001	+0.0001	+0.0002	+0.0002	+0.0002	+0.0002	+0.0002	+0.0001	+0.0001	-0.0000	-0.0001	-0.0001	-0.0002	-0.0002
31	-0.0002	-0.0002	-0.0002	-0.0001	-0.0001	+0.0000	+0.0001	+0.0001	+0.0002	+0.0002	+0.0002	+0.0002	+0.0002	+0.0001	+0.0001	-0.0000	-0.0001	-0.0001	-0.0002	-0.0002
32	-0.0002	-0.0002	-0.0002	-0.0001	-0.0001	+0.0000	+0.0001	+0.0001	+0.0002	+0.0002	+0.0002	+0.0002	+0.0002	+0.0001	+0.0001	-0.0000	-0.0001	-0.0001	-0.0002	-0.0002

AERIAL GAIN PER TIER

P = 3·0 Q = -4·0 G = 0·5078

NUMBER OF TIERS

INTER-TIER SPACING	2	3	4	5	6	8
0·25	0·3050	0·2670	0·2715	0·2841	0·2893	0·2900
0·3	0·3299	0·3160	0·3354	0·3447	0·3446	0·3509
0·35	0·3611	0·3744	0·3972	0·3987	0·4023	0·4087
0·4	0·3992	0·4371	0·4514	0·4537	0·4621	0·4672
0·45	0·4445	0·4972	0·5015	0·5125	0·5179	0·5255
0·5	0·4964	0·5495	0·5540	0·5691	0·5726	0·5818
0·55	0·5531	0·5937	0·6102	0·6207	0·6296	0·6393
0·6	0·6106	0·6346	0·6648	0·6719	0·6837	0·6941
0·65	0·6630	0·6778	0·7119	0·7259	0·7340	0·7488
0·7	0·7033	0·7257	0·7525	0·7763	0·7860	0·8022
0·75	0·7255	0·7745	0·7938	0·8178	0·8357	0·8516
0·8	0·7271	0·8126	0·8389	0·8567	0·8755	0·9015
0·85	0·7102	0·8244	0·8755	0·8986	0·9137	0·9410
0·9	0·6800	0·7998	0·8756	0·9210	0·9477	0·9765
0·95	0·6429	0·7441	0·8205	0·8785	0·9227	0·9822
1·0	0·6044	0·6736	0·7261	0·7678	0·8018	0·8545
1·05	0·5682	0·6047	0·6280	0·6435	0·6540	0·6661
1·1	0·5365	0·5469	0·5495	0·5487	0·5468	0·5433
1·15	0·5103	0·5035	0·4958	0·4900	0·4863	0·4830
1·2	0·4898	0·4737	0·4637	0·4585	0·4560	0·4527
1·25	0·4748	0·4557	0·4473	0·4436	0·4412	0·4374
1·3	0·4650	0·4471	0·4410	0·4377	0·4348	0·4318
1·35	0·4600	0·4456	0·4408	0·4371	0·4347	0·4319
1·4	0·4593	0·4488	0·4441	0·4406	0·4388	0·4362
1·45	0·4624	0·4552	0·4501	0·4475	0·4457	0·4435
1·5	0·4686	0·4632	0·4584	0·4565	0·4548	0·4529
1·55	0·4774	0·4723	0·4688	0·4669	0·4657	0·4642
1·6	0·4880	0·4824	0·4806	0·4787	0·4779	0·4766
1·65	0·4995	0·4937	0·4929	0·4917	0·4909	0·4901
1·7	0·5110	0·5064	0·5056	0·5055	0·5049	0·5045
1·75	0·5213	0·5199	0·5189	0·5193	0·5195	0·5193

NUMBER OF TIERS

INTER-TIER SPACING	8	10	12	16	20	24	32
0·7	0·8022	0·8111	0·8184	0·8266	0·8318	0·8353	0·8397
0·72	0·8221	0·8328	0·8401	0·8492	0·8547	0·8584	0·8631
0·74	0·8417	0·8543	0·8612	0·8712	0·8772	0·8812	0·8863
0·76	0·8617	0·8748	0·8825	0·8931	0·8996	0·9040	0·9095
0·78	0·8819	0·8942	0·9038	0·9150	0·9218	0·9265	0·9324
0·8	0·9015	0·9135	0·9241	0·9360	0·9435	0·9487	0·9552
0·82	0·9190	0·9332	0·9432	0·9568	0·9653	0·9707	0·9777
0·84	0·9341	0·9522	0·9622	0·9775	0·9861	0·9922	0·9999
0·86	0·9478	0·9688	0·9813	0·9966	1·0066	1·0134	1·0219
0·88	0·9619	0·9825	0·9982	1·0150	1·0264	1·0336	1·0431
0·9	0·9765	0·9954	1·0116	1·0331	1·0444	1·0532	1·0637
0·92	0·9883	1·0089	1·0238	1·0473	1·0620	1·0708	1·0833
0·94	0·9891	1·0183	1·0359	1·0584	1·0750	1·0870	1·1007
0·96	0·9691	1·0101	1·0370	1·0679	1·0851	1·0972	1·1150
0·98	0·9228	0·9691	1·0038	1·0511	1·0805	1·0998	1·1223
1·0	0·8545	0·8938	0·9245	0·9697	1·0016	1·0256	1·0595
1·02	0·7762	0·8007	0·8185	0·8416	0·8554	0·8640	0·8736
1·04	0·7004	0·7111	0·7173	0·7233	0·7262	0·7283	0·7318
1·06	0·6351	0·6373	0·6379	0·6388	0·6401	0·6412	0·6420
1·08	0·5830	0·5818	0·5812	0·5815	0·5816	0·5815	0·5815
1·1	0·5433	0·5415	0·5410	0·5404	0·5396	0·5393	0·5388
1·12	0·5137	0·5123	0·5114	0·5099	0·5091	0·5085	0·5078
1·14	0·4918	0·4903	0·4889	0·4872	0·4863	0·4856	0·4848
1·16	0·4753	0·4733	0·4718	0·4701	0·4690	0·4684	0·4675
1·18	0·4626	0·4602	0·4588	0·4571	0·4560	0·4553	0·4545
1·2	0·4527	0·4503	0·4490	0·4472	0·4462	0·4455	0·4446
1·22	0·4451	0·4430	0·4417	0·4399	0·4389	0·4382	0·4373
1·24	0·4396	0·4376	0·4362	0·4345	0·4335	0·4329	0·4320
1·26	0·4357	0·4338	0·4324	0·4308	0·4298	0·4292	0·4284
1·28	0·4332	0·4313	0·4300	0·4284	0·4275	0·4268	0·4261
1·3	0·4318	0·4298	0·4287	0·4271	0·4262	0·4256	0·4249

RELATIVE MUTUAL RESISTANCE

P = −1·0   Q = 0·25

X/λ	·00	·05	·10	·15	·20	·25	·30	·35	·40	·45	·50	·55	·60	·65	·70	·75	·80	·85	·90	·95
0	+1.0000	+0.9884	+0.9542	+0.8991	+0.8257	+0.7375	+0.6388	+0.5339	+0.4275	+0.3240	+0.2273	+0.1410	+0.0674	+0.0084	−0.0355	−0.0643	−0.0792	−0.0818	−0.0745	−0.0599
1	−0.0407	−0.0196	+0.0009	+0.0189	+0.0328	+0.0418	+0.0454	+0.0439	+0.0379	+0.0284	+0.0168	+0.0042	−0.0078	−0.0182	−0.0261	−0.0307	−0.0320	−0.0299	−0.0250	−0.0178
2	−0.0092	−0.0001	+0.0085	+0.0158	+0.0212	+0.0242	+0.0247	+0.0226	+0.0185	+0.0126	+0.0058	−0.0013	−0.0080	−0.0137	−0.0178	−0.0199	−0.0200	−0.0182	−0.0146	−0.0097
3	−0.0040	+0.0019	+0.0074	+0.0120	+0.0153	+0.0169	+0.0169	+0.0152	+0.0120	+0.0078	+0.0029	−0.0021	−0.0063	−0.0106	−0.0134	−0.0147	−0.0146	−0.0130	−0.0102	−0.0065
4	−0.0022	+0.0021	+0.0062	+0.0095	+0.0119	+0.0130	+0.0126	+0.0114	+0.0089	+0.0055	+0.0018	−0.0021	−0.0057	−0.0086	−0.0107	−0.0116	−0.0114	−0.0101	−0.0078	−0.0048
5	−0.0014	+0.0021	+0.0053	+0.0079	+0.0097	+0.0105	+0.0103	+0.0091	+0.0070	+0.0043	+0.0012	−0.0020	−0.0049	−0.0073	−0.0089	−0.0096	−0.0094	−0.0083	−0.0063	−0.0038
6	−0.0010	+0.0019	+0.0046	+0.0067	+0.0082	+0.0089	+0.0086	+0.0076	+0.0058	+0.0035	+0.0008	−0.0018	−0.0043	−0.0063	−0.0076	−0.0082	−0.0080	−0.0070	−0.0053	−0.0032
7	−0.0007	+0.0018	+0.0040	+0.0059	+0.0071	+0.0076	+0.0074	+0.0065	+0.0049	+0.0029	+0.0006	−0.0017	−0.0038	−0.0055	−0.0067	−0.0072	−0.0069	−0.0061	−0.0046	−0.0027
8	−0.0006	+0.0016	+0.0036	+0.0052	+0.0063	+0.0067	+0.0065	+0.0057	+0.0043	+0.0025	+0.0005	−0.0015	−0.0034	−0.0049	−0.0059	−0.0063	−0.0061	−0.0053	−0.0040	−0.0023
9	−0.0004	+0.0015	+0.0032	+0.0047	+0.0056	+0.0060	+0.0058	+0.0050	+0.0038	+0.0022	+0.0004	−0.0014	−0.0031	−0.0044	−0.0053	−0.0057	−0.0055	−0.0048	−0.0036	−0.0021
10	−0.0004	+0.0014	+0.0029	+0.0042	+0.0051	+0.0054	+0.0052	+0.0045	+0.0034	+0.0019	+0.0003	−0.0013	−0.0028	−0.0040	−0.0048	−0.0052	−0.0050	−0.0043	−0.0032	−0.0018
11	−0.0003	+0.0013	+0.0027	+0.0039	+0.0046	+0.0049	+0.0048	+0.0041	+0.0031	+0.0018	+0.0003	−0.0012	−0.0026	−0.0037	−0.0044	−0.0047	−0.0046	−0.0039	−0.0029	−0.0017
12	−0.0002	+0.0012	+0.0025	+0.0036	+0.0043	+0.0045	+0.0044	+0.0038	+0.0028	+0.0016	+0.0002	−0.0012	−0.0024	−0.0034	−0.0041	−0.0044	−0.0042	−0.0036	−0.0027	−0.0015
13	−0.0002	+0.0011	+0.0023	+0.0033	+0.0039	+0.0042	+0.0040	+0.0035	+0.0026	+0.0015	+0.0002	−0.0011	−0.0022	−0.0032	−0.0038	−0.0040	−0.0039	−0.0033	−0.0025	−0.0014
14	−0.0002	+0.0011	+0.0022	+0.0031	+0.0037	+0.0039	+0.0037	+0.0032	+0.0024	+0.0013	+0.0002	−0.0010	−0.0021	−0.0030	−0.0035	−0.0038	−0.0036	−0.0031	−0.0023	−0.0013
15	−0.0002	+0.0010	+0.0020	+0.0029	+0.0034	+0.0036	+0.0035	+0.0030	+0.0022	+0.0013	+0.0001	−0.0010	−0.0020	−0.0028	−0.0033	−0.0035	−0.0034	−0.0029	−0.0022	−0.0012
16	−0.0001	+0.0009	+0.0019	+0.0027	+0.0032	+0.0034	+0.0033	+0.0028	+0.0021	+0.0012	+0.0001	−0.0009	−0.0019	−0.0026	−0.0031	−0.0033	−0.0032	−0.0027	−0.0020	−0.0011
17	−0.0001	+0.0009	+0.0018	+0.0025	+0.0030	+0.0032	+0.0031	+0.0027	+0.0020	+0.0011	+0.0001	−0.0009	−0.0018	−0.0025	−0.0029	−0.0031	−0.0030	−0.0026	−0.0019	−0.0011
18	−0.0001	+0.0008	+0.0017	+0.0024	+0.0029	+0.0030	+0.0029	+0.0025	+0.0019	+0.0010	+0.0001	−0.0008	−0.0017	−0.0023	−0.0028	−0.0030	−0.0028	−0.0024	−0.0018	−0.0010
19	−0.0001	+0.0008	+0.0016	+0.0023	+0.0027	+0.0029	+0.0028	+0.0024	+0.0018	+0.0010	+0.0001	−0.0008	−0.0016	−0.0022	−0.0027	−0.0028	−0.0027	−0.0023	−0.0017	−0.0009
20	−0.0001	+0.0008	+0.0016	+0.0022	+0.0026	+0.0027	+0.0026	+0.0023	+0.0017	+0.0009	+0.0001	−0.0008	−0.0015	−0.0021	−0.0025	−0.0027	−0.0026	−0.0022	−0.0016	−0.0009
21	−0.0001	+0.0007	+0.0015	+0.0021	+0.0025	+0.0026	+0.0025	+0.0021	+0.0016	+0.0009	+0.0001	−0.0007	−0.0014	−0.0020	−0.0024	−0.0026	−0.0024	−0.0021	−0.0015	−0.0009
22	−0.0001	+0.0007	+0.0014	+0.0020	+0.0024	+0.0025	+0.0024	+0.0021	+0.0015	+0.0008	+0.0001	−0.0007	−0.0014	−0.0019	−0.0023	−0.0024	−0.0023	−0.0020	−0.0015	−0.0008
23	−0.0001	+0.0007	+0.0014	+0.0019	+0.0023	+0.0024	+0.0023	+0.0020	+0.0014	+0.0008	+0.0001	−0.0007	−0.0013	−0.0019	−0.0022	−0.0023	−0.0022	−0.0019	−0.0014	−0.0008
24	−0.0001	+0.0007	+0.0013	+0.0018	+0.0022	+0.0023	+0.0022	+0.0019	+0.0014	+0.0008	+0.0001	−0.0006	−0.0013	−0.0018	−0.0021	−0.0022	−0.0021	−0.0018	−0.0014	−0.0007
25	−0.0001	+0.0006	+0.0013	+0.0018	+0.0021	+0.0022	+0.0021	+0.0018	+0.0013	+0.0007	+0.0001	−0.0006	−0.0012	−0.0017	−0.0020	−0.0022	−0.0021	−0.0018	−0.0013	−0.0007
26	−0.0001	+0.0006	+0.0012	+0.0017	+0.0020	+0.0021	+0.0020	+0.0017	+0.0013	+0.0007	+0.0001	−0.0006	−0.0012	−0.0017	−0.0020	−0.0021	−0.0020	−0.0017	−0.0013	−0.0007
27	−0.0000	+0.0006	+0.0012	+0.0016	+0.0019	+0.0020	+0.0019	+0.0017	+0.0012	+0.0007	+0.0000	−0.0006	−0.0011	−0.0016	−0.0019	−0.0020	−0.0019	−0.0016	−0.0012	−0.0007
28	−0.0000	+0.0006	+0.0011	+0.0016	+0.0019	+0.0020	+0.0019	+0.0016	+0.0012	+0.0006	+0.0000	−0.0006	−0.0011	−0.0015	−0.0018	−0.0019	−0.0018	−0.0016	−0.0012	−0.0006
29	−0.0000	+0.0006	+0.0011	+0.0015	+0.0018	+0.0019	+0.0018	+0.0016	+0.0011	+0.0006	+0.0000	−0.0005	−0.0011	−0.0015	−0.0018	−0.0019	−0.0018	−0.0015	−0.0011	−0.0006
30	−0.0000	+0.0005	+0.0011	+0.0015	+0.0017	+0.0018	+0.0018	+0.0015	+0.0011	+0.0006	+0.0000	−0.0005	−0.0010	−0.0014	−0.0017	−0.0018	−0.0017	−0.0015	−0.0011	−0.0006
31	−0.0000	+0.0005	+0.0010	+0.0014	+0.0017	+0.0018	+0.0017	+0.0015	+0.0011	+0.0006	+0.0000	−0.0005	−0.0010	−0.0014	−0.0017	−0.0017	−0.0017	−0.0014	−0.0011	−0.0006
32	−0.0000	+0.0005	+0.0010	+0.0014	+0.0016	+0.0017	+0.0016	+0.0014	+0.0010	+0.0006	+0.0000	−0.0005	−0.0010	−0.0014	−0.0016	−0.0017	−0.0016	−0.0014	−0.0010	−0.0006

AERIAL GAIN PER TIER

P = -1·0   Q = 0·25   G = 0·8503

INTER-TIER SPACING	NUMBER OF TIERS 2	3	4	5	6	8
0·25	0·4894	0·3983	0·3695	0·3565	0·3464	0·3344
0·3	0·5189	0·4483	0·4277	0·4135	0·4035	0·3942
0·35	0·5544	0·5037	0·4844	0·4695	0·4627	0·4526
0·4	0·5957	0·5605	0·5387	0·5275	0·5212	0·5123
0·45	0·6423	0·6152	0·5932	0·5859	0·5780	0·5706
0·5	0·6928	0·6664	0·6498	0·6420	0·6359	0·6291
0·55	0·7453	0·7155	0·7067	0·6967	0·6939	0·6876
0·6	0·7966	0·7648	0·7606	0·7531	0·7491	0·7444
0·65	0·8433	0·8165	0·8105	0·8095	0·8044	0·8025
0·7	0·8816	0·8695	0·8598	0·8611	0·8611	0·8576
0·75	0·9088	0·9188	0·9120	0·9094	0·9125	0·9130
0·8	0·9234	0·9562	0·9633	0·9610	0·9602	0·9669
0·85	0·9261	0·9734	0·9997	1·0104	1·0124	1·0128
0·9	0·9188	0·9670	1·0035	1·0301	1·0479	1·0634
0·95	0·9045	0·9412	0·9706	0·9959	1·0182	1·0554
1·0	0·8864	0·9050	0·9166	0·9245	0·9304	0·9385
1·05	0·8674	0·8682	0·8633	0·8563	0·8487	0·8344
1·1	0·8496	0·8375	0·8248	0·8146	0·8076	0·8019
1·15	0·8346	0·8164	0·8046	0·7994	0·7983	0·7987
1·2	0·8233	0·8052	0·7989	0·7987	0·7987	0·7953
1·25	0·8162	0·8025	0·8013	0·8011	0·7987	0·7966
1·3	0·8134	0·8058	0·8060	0·8031	0·8010	0·8004
1·35	0·8146	0·8124	0·8105	0·8072	0·8071	0·8052
1·4	0·8193	0·8198	0·8155	0·8144	0·8138	0·8126
1·45	0·8268	0·8270	0·8226	0·8229	0·8211	0·8204
1·5	0·8363	0·8339	0·8320	0·8312	0·8305	0·8297
1·55	0·8467	0·8414	0·8424	0·8402	0·8408	0·8399
1·6	0·8570	0·8505	0·8522	0·8512	0·8507	0·8504
1·65	0·8661	0·8616	0·8614	0·8628	0·8618	0·8624
1·7	0·8731	0·8737	0·8716	0·8733	0·8742	0·8738
1·75	0·8773	0·8849	0·8838	0·8835	0·8852	0·8861

INTER-TIER SPACING	NUMBER OF TIERS 8	10	12	16	20	24	32
0·7	0·8576	0·8571	0·8566	0·8558	0·8551	0·8547	0·8544
0·72	0·8793	0·8802	0·8790	0·8788	0·8787	0·8785	0·8782
0·74	0·9016	0·9025	0·9017	0·9018	0·9018	0·9019	0·9019
0·76	0·9244	0·9238	0·9250	0·9253	0·9255	0·9256	0·9257
0·78	0·9465	0·9453	0·9474	0·9479	0·9483	0·9486	0·9493
0·8	0·9669	0·9678	0·9685	0·9701	0·9714	0·9722	0·9727
0·82	0·9854	0·9902	0·9899	0·9932	0·9943	0·9948	0·9963
0·84	1·0034	1·0103	1·0125	1·0150	1·0162	1·0181	1·0192
0·86	1·0228	1·0278	1·0337	1·0354	1·0392	1·0399	1·0422
0·88	1·0439	1·0454	1·0510	1·0577	1·0596	1·0626	1·0650
0·9	1·0634	1·0658	1·0676	1·0775	1·0808	1·0829	1·0863
0·92	1·0739	1·0853	1·0880	1·0920	1·1006	1·1041	1·1080
0·94	1·0670	1·0908	1·1038	1·1111	1·1136	1·1199	1·1278
0·96	1·0384	1·0673	1·0903	1·1199	1·1321	1·1352	1·1394
0·98	0·9921	1·0129	1·0318	1·0653	1·0935	1·1163	1·1457
1·0	0·9385	0·9440	0·9479	0·9532	0·9566	0·9591	0·9623
1·02	0·8886	0·8814	0·8737	0·8587	0·8457	0·8354	0·8227
1·04	0·8492	0·8376	0·8281	0·8165	0·8124	0·8121	0·8119
1·06	0·8229	0·8137	0·8091	0·8077	0·8081	0·8062	0·8038
1·08	0·8082	0·8045	0·8043	0·8043	0·8015	0·8006	0·7997
1·1	0·8019	0·8019	0·8022	0·7990	0·7981	0·7977	0·7968
1·12	0·8000	0·8003	0·7986	0·7962	0·7959	0·7949	0·7942
1·14	0·7992	0·7977	0·7954	0·7950	0·7936	0·7935	0·7927
1·16	0·7981	0·7953	0·7943	0·7934	0·7929	0·7921	0·7917
1·18	0·7965	0·7941	0·7942	0·7926	0·7921	0·7918	0·7911
1·2	0·7953	0·7943	0·7939	0·7928	0·7920	0·7915	0·7912
1·22	0·7951	0·7950	0·7937	0·7929	0·7924	0·7920	0·7915
1·24	0·7959	0·7955	0·7943	0·7935	0·7930	0·7927	0·7923
1·26	0·7974	0·7961	0·7957	0·7948	0·7943	0·7939	0·7935
1·28	0·7989	0·7973	0·7971	0·7961	0·7956	0·7953	0·7949
1·3	0·8004	0·7992	0·7985	0·7978	0·7974	0·7971	0·7967

RELATIVE MUTUAL RESISTANCE

ISOTROPIC SOURCES

P = 0·0 Q = 0·0

X/λ	.00	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75	.80	.85	.90	.95
0	+1.0000	+0.9836	+0.9355	+0.8584	+0.7568	+0.6366	+0.5046	+0.3679	+0.2339	+0.1093	+0.0000	-0.0894	-0.1559	-0.1981	-0.2162	-0.2122	-0.1892	-0.1515	-0.1039	-0.0518
1	+0.0000	+0.0466	+0.0850	+0.1120	+0.1261	+0.1273	+0.1164	+0.0954	+0.0668	+0.0339	+0.0000	-0.0317	-0.0585	-0.0780	-0.0890	-0.0909	-0.0841	-0.0696	-0.0492	-0.0252
2	+0.0000	+0.0240	+0.0445	+0.0599	+0.0688	+0.0707	+0.0658	+0.0548	+0.0390	+0.0201	+0.0000	-0.0193	-0.0350	-0.0486	-0.0561	-0.0579	-0.0541	-0.0452	-0.0323	-0.0167
3	+0.0000	+0.0161	+0.0302	+0.0409	+0.0473	+0.0490	+0.0459	+0.0384	+0.0275	+0.0143	+0.0000	-0.0139	-0.0260	-0.0353	-0.0409	-0.0424	-0.0398	-0.0334	-0.0240	-0.0125
4	+0.0000	+0.0121	+0.0228	+0.0310	+0.0360	+0.0374	+0.0352	+0.0296	+0.0213	+0.0111	+0.0000	-0.0108	-0.0203	-0.0277	-0.0322	-0.0335	-0.0315	-0.0265	-0.0191	-0.0099
5	+0.0000	+0.0097	+0.0183	+0.0250	+0.0291	+0.0303	+0.0286	+0.0241	+0.0173	+0.0090	+0.0000	-0.0089	-0.0167	-0.0228	-0.0266	-0.0277	-0.0261	-0.0220	-0.0159	-0.0083
6	+0.0000	+0.0081	+0.0153	+0.0209	+0.0244	+0.0255	+0.0240	+0.0203	+0.0146	+0.0076	+0.0000	-0.0075	-0.0142	-0.0194	-0.0226	-0.0236	-0.0223	-0.0188	-0.0136	-0.0071
7	+0.0000	+0.0070	+0.0132	+0.0180	+0.0210	+0.0220	+0.0207	+0.0175	+0.0126	+0.0066	+0.0000	-0.0065	-0.0123	-0.0168	-0.0197	-0.0205	-0.0194	-0.0164	-0.0118	-0.0062
8	+0.0000	+0.0061	+0.0115	+0.0158	+0.0185	+0.0193	+0.0182	+0.0154	+0.0111	+0.0058	+0.0000	-0.0058	-0.0109	-0.0149	-0.0174	-0.0182	-0.0172	-0.0145	-0.0105	-0.0055
9	+0.0000	+0.0054	+0.0103	+0.0141	+0.0165	+0.0172	+0.0163	+0.0138	+0.0100	+0.0052	+0.0000	-0.0051	-0.0097	-0.0133	-0.0156	-0.0163	-0.0154	-0.0131	-0.0094	-0.0049
10	+0.0000	+0.0049	+0.0093	+0.0127	+0.0148	+0.0155	+0.0147	+0.0124	+0.0090	+0.0047	+0.0000	-0.0047	-0.0088	-0.0121	-0.0141	-0.0148	-0.0140	-0.0119	-0.0086	-0.0045
11	+0.0000	+0.0045	+0.0084	+0.0115	+0.0135	+0.0141	+0.0134	+0.0113	+0.0082	+0.0043	+0.0000	-0.0043	-0.0081	-0.0111	-0.0129	-0.0135	-0.0128	-0.0109	-0.0079	-0.0041
12	+0.0000	+0.0041	+0.0077	+0.0106	+0.0124	+0.0130	+0.0123	+0.0104	+0.0075	+0.0040	+0.0000	-0.0039	-0.0074	-0.0102	-0.0119	-0.0125	-0.0118	-0.0100	-0.0073	-0.0038
13	+0.0000	+0.0038	+0.0071	+0.0098	+0.0115	+0.0120	+0.0114	+0.0096	+0.0070	+0.0037	+0.0000	-0.0036	-0.0069	-0.0094	-0.0110	-0.0116	-0.0110	-0.0093	-0.0067	-0.0035
14	+0.0000	+0.0035	+0.0066	+0.0091	+0.0107	+0.0112	+0.0106	+0.0090	+0.0065	+0.0034	+0.0000	-0.0034	-0.0064	-0.0088	-0.0103	-0.0108	-0.0102	-0.0087	-0.0063	-0.0033
15	+0.0000	+0.0033	+0.0062	+0.0085	+0.0100	+0.0104	+0.0099	+0.0084	+0.0061	+0.0032	+0.0000	-0.0032	-0.0060	-0.0082	-0.0096	-0.0101	-0.0096	-0.0081	-0.0059	-0.0031
16	+0.0000	+0.0031	+0.0058	+0.0080	+0.0093	+0.0098	+0.0093	+0.0079	+0.0057	+0.0030	+0.0000	-0.0030	-0.0056	-0.0077	-0.0091	-0.0095	-0.0090	-0.0076	-0.0055	-0.0029
17	+0.0000	+0.0029	+0.0055	+0.0075	+0.0088	+0.0092	+0.0087	+0.0074	+0.0054	+0.0028	+0.0000	-0.0028	-0.0053	-0.0073	-0.0086	-0.0090	-0.0085	-0.0072	-0.0052	-0.0027
18	+0.0000	+0.0027	+0.0052	+0.0071	+0.0083	+0.0087	+0.0083	+0.0070	+0.0051	+0.0027	+0.0000	-0.0027	-0.0050	-0.0069	-0.0081	-0.0085	-0.0081	-0.0068	-0.0049	-0.0026
19	+0.0000	+0.0026	+0.0049	+0.0067	+0.0079	+0.0083	+0.0078	+0.0067	+0.0048	+0.0025	+0.0000	-0.0025	-0.0048	-0.0066	-0.0077	-0.0081	-0.0076	-0.0065	-0.0047	-0.0025
20	+0.0000	+0.0025	+0.0047	+0.0064	+0.0075	+0.0079	+0.0075	+0.0063	+0.0046	+0.0024	+0.0000	-0.0024	-0.0045	-0.0062	-0.0073	-0.0077	-0.0073	-0.0062	-0.0045	-0.0023
21	+0.0000	+0.0023	+0.0044	+0.0061	+0.0071	+0.0075	+0.0071	+0.0060	+0.0044	+0.0023	+0.0000	-0.0023	-0.0043	-0.0059	-0.0070	-0.0073	-0.0069	-0.0059	-0.0043	-0.0022
22	+0.0000	+0.0022	+0.0042	+0.0058	+0.0068	+0.0072	+0.0068	+0.0058	+0.0042	+0.0022	+0.0000	-0.0022	-0.0041	-0.0057	-0.0067	-0.0070	-0.0066	-0.0056	-0.0041	-0.0021
23	+0.0000	+0.0021	+0.0040	+0.0056	+0.0065	+0.0068	+0.0065	+0.0055	+0.0040	+0.0021	+0.0000	-0.0021	-0.0040	-0.0054	-0.0064	-0.0067	-0.0064	-0.0054	-0.0039	-0.0021
24	+0.0000	+0.0020	+0.0039	+0.0053	+0.0063	+0.0066	+0.0062	+0.0053	+0.0038	+0.0020	+0.0000	-0.0020	-0.0038	-0.0052	-0.0061	-0.0064	-0.0061	-0.0052	-0.0038	-0.0020
25	+0.0000	+0.0020	+0.0037	+0.0051	+0.0060	+0.0063	+0.0060	+0.0051	+0.0037	+0.0019	+0.0000	-0.0019	-0.0037	-0.0050	-0.0059	-0.0062	-0.0059	-0.0050	-0.0036	-0.0019
26	+0.0000	+0.0019	+0.0036	+0.0049	+0.0058	+0.0061	+0.0058	+0.0049	+0.0035	+0.0019	+0.0000	-0.0019	-0.0035	-0.0048	-0.0057	-0.0059	-0.0056	-0.0048	-0.0035	-0.0018
27	+0.0000	+0.0018	+0.0035	+0.0047	+0.0056	+0.0058	+0.0055	+0.0047	+0.0034	+0.0018	+0.0000	-0.0018	-0.0034	-0.0047	-0.0055	-0.0057	-0.0054	-0.0046	-0.0034	-0.0018
28	+0.0000	+0.0018	+0.0033	+0.0046	+0.0054	+0.0056	+0.0053	+0.0045	+0.0033	+0.0017	+0.0000	-0.0017	-0.0033	-0.0045	-0.0053	-0.0055	-0.0053	-0.0045	-0.0032	-0.0017
29	+0.0000	+0.0017	+0.0032	+0.0044	+0.0052	+0.0054	+0.0052	+0.0044	+0.0032	+0.0017	+0.0000	-0.0017	-0.0032	-0.0043	-0.0051	-0.0053	-0.0051	-0.0043	-0.0031	-0.0016
30	+0.0000	+0.0016	+0.0031	+0.0043	+0.0050	+0.0053	+0.0050	+0.0042	+0.0031	+0.0016	+0.0000	-0.0016	-0.0031	-0.0042	-0.0049	-0.0052	-0.0049	-0.0042	-0.0030	-0.0016
31	+0.0000	+0.0016	+0.0030	+0.0041	+0.0049	+0.0051	+0.0048	+0.0041	+0.0030	+0.0016	+0.0000	-0.0016	-0.0030	-0.0041	-0.0048	-0.0050	-0.0048	-0.0040	-0.0029	-0.0015
32	+0.0000	+0.0015	+0.0029	+0.0040	+0.0047	+0.0049	+0.0047	+0.0040	+0.0029	+0.0015	+0.0000	-0.0015	-0.0029	-0.0039	-0.0046	-0.0049	-0.0046	-0.0039	-0.0028	-0.0015

AERIAL GAIN PER TIER

ISOTROPIC SOURCES

P = 0·0 Q = 0·0 G = 0·6094

INTER-TIER SPACING	NUMBER OF TIERS: 2	3	4	5	6	8
0.25	0.3724	0.3296	0.3296	0.3296	0.3222	0.3171
0.3	0.4050	0.3885	0.3934	0.3839	0.3778	0.3775
0.35	0.4455	0.4526	0.4484	0.4374	0.4397	0.4341
0.4	0.4939	0.5140	0.4976	0.4976	0.4976	0.4952
0.45	0.5494	0.5661	0.5502	0.5577	0.5508	0.5511
0.5	0.6094	0.6094	0.6094	0.6094	0.6094	0.6094
0.55	0.6693	0.6501	0.6683	0.6595	0.6676	0.6671
0.6	0.7220	0.6955	0.7168	0.7168	0.7168	0.7201
0.65	0.7600	0.7491	0.7555	0.7732	0.7693	0.7788
0.7	0.7775	0.8059	0.7969	0.8145	0.8267	0.8272
0.75	0.7736	0.8499	0.8499	0.8499	0.8670	0.8796
0.8	0.7516	0.8578	0.8999	0.8999	0.8999	0.9272
0.85	0.7182	0.8250	0.9040	0.9428	0.9517	0.9523
0.9	0.6801	0.7567	0.8326	0.8995	0.9503	0.9981
0.95	0.6427	0.6785	0.7165	0.7561	0.7964	0.8756
1.0	0.6094	0.6094	0.6094	0.6094	0.6094	0.6094
1.05	0.5821	0.5580	0.5368	0.5184	0.5026	0.4780
1.1	0.5616	0.5257	0.4998	0.4822	0.4711	0.4622
1.15	0.5481	0.5108	0.4911	0.4831	0.4814	0.4813
1.2	0.5412	0.5103	0.5015	0.5015	0.5015	0.4961
1.25	0.5406	0.5210	0.5210	0.5210	0.5172	0.5146
1.3	0.5459	0.5387	0.5409	0.5367	0.5339	0.5337
1.35	0.5564	0.5592	0.5575	0.5530	0.5540	0.5516
1.4	0.5712	0.5787	0.5727	0.5727	0.5727	0.5717
1.45	0.5894	0.5953	0.5897	0.5924	0.5899	0.5901
1.5	0.6094	0.6094	0.6094	0.6094	0.6094	0.6094
1.55	0.6294	0.6232	0.6291	0.6263	0.6288	0.6287
1.6	0.6473	0.6391	0.6457	0.6457	0.6457	0.6467
1.65	0.6610	0.6577	0.6596	0.6649	0.6637	0.6665
1.7	0.6690	0.6774	0.6748	0.6799	0.6834	0.6835
1.75	0.6704	0.6935	0.6935	0.6935	0.6983	0.7018

INTER-TIER SPACING	NUMBER OF TIERS: 8	10	12	16	20	24	32
0.7	0.8272	0.8340	0.8378	0.8418	0.8434	0.8447	0.8472
0.72	0.8463	0.8572	0.8575	0.8632	0.8665	0.8684	0.8705
0.74	0.8680	0.8770	0.8789	0.8846	0.8880	0.8904	0.8933
0.76	0.8913	0.8940	0.9024	0.9081	0.9116	0.9139	0.9169
0.78	0.9122	0.9124	0.9228	0.9284	0.9322	0.9351	0.9393
0.8	0.9272	0.9347	0.9388	0.9476	0.9542	0.9583	0.9616
0.82	0.9366	0.9566	0.9567	0.9706	0.9757	0.9781	0.9845
0.84	0.9457	0.9705	0.9793	0.9887	0.9935	1.0007	1.0052
0.86	0.9608	0.9761	0.9968	1.0025	1.0160	1.0182	1.0263
0.88	0.9822	0.9841	1.0012	1.0239	1.0292	1.0393	1.0473
0.9	0.9981	1.0029	1.0055	1.0363	1.0463	1.0520	1.0628
0.92	0.9849	1.0186	1.0241	1.0315	1.0585	1.0690	1.0802
0.94	0.9234	0.9890	1.0273	1.0454	1.0486	1.0671	1.0917
0.96	0.8209	0.8844	0.9420	1.0250	1.0606	1.0670	1.0753
0.98	0.7073	0.7388	0.7712	0.8376	0.9023	0.9610	1.0457
1.0	0.6094	0.6094	0.6094	0.6094	0.6094	0.6094	0.6094
1.02	0.5379	0.5217	0.5072	0.4830	0.4645	0.4509	0.4350
1.04	0.4923	0.4735	0.4596	0.4434	0.4376	0.4366	0.4353
1.06	0.4682	0.4547	0.4479	0.4449	0.4444	0.4415	0.4379
1.08	0.4600	0.4540	0.4531	0.4519	0.4476	0.4461	0.4444
1.1	0.4622	0.4613	0.4609	0.4558	0.4542	0.4534	0.4517
1.12	0.4694	0.4691	0.4661	0.4624	0.4615	0.4599	0.4587
1.14	0.4776	0.4748	0.4712	0.4703	0.4681	0.4677	0.4665
1.16	0.4846	0.4801	0.4785	0.4769	0.4761	0.4749	0.4742
1.18	0.4904	0.4867	0.4867	0.4842	0.4833	0.4829	0.4818
1.2	0.4961	0.4947	0.4939	0.4923	0.4911	0.4904	0.4898
1.22	0.5027	0.5027	0.5007	0.4996	0.4990	0.4984	0.4977
1.24	0.5105	0.5099	0.5083	0.5072	0.5065	0.5061	0.5055
1.26	0.5187	0.5168	0.5164	0.5153	0.5146	0.5141	0.5136
1.28	0.5265	0.5242	0.5241	0.5229	0.5223	0.5219	0.5215
1.3	0.5337	0.5322	0.5314	0.5306	0.5302	0.5299	0.5294

RELATIVE MUTUAL RESISTANCE

λ/2 DIPOLE TURNSTILES

P = 0·8806   Q = 0·3598

X/λ	·00	·05	·10	·15	·20	·25	·30	·35	·40	·45	·50	·55	·60	·65	·70	·75	·80	·85	·90	·95
0	+1·0000	+0·9798	+0·9206	+0·8262	+0·7025	+0·5572	+0·3994	+0·2385	+0·0840	−0·0554	−0·1726	−0·2618	−0·3200	−0·3459	−0·3409	−0·3084	−0·2534	−0·1823	−0·1024	−0·0209
1	+0·0553	+0·1203	+0·1693	+0·1994	+0·2095	+0·1999	+0·1730	+0·1323	+0·0822	+0·0279	−0·0256	−0·0734	−0·1117	−0·1373	−0·1489	−0·1459	−0·1295	−0·1019	−0·0662	−0·0261
2	+0·0146	+0·0519	+0·0827	+0·1042	+0·1150	+0·1145	+0·1032	+0·0825	+0·0550	+0·0233	−0·0094	−0·0399	−0·0655	−0·0839	−0·0936	−0·0941	−0·0856	−0·0692	−0·0468	−0·0207
3	+0·0065	+0·0323	+0·0541	+0·0701	+0·0789	+0·0798	+0·0731	+0·0596	+0·0407	+0·0185	−0·0048	−0·0271	−0·0461	−0·0602	−0·0681	−0·0693	−0·0638	−0·0523	−0·0360	−0·0167
4	+0·0037	+0·0233	+0·0401	+0·0527	+0·0599	+0·0612	+0·0566	+0·0466	+0·0323	+0·0152	−0·0029	−0·0204	−0·0355	−0·0469	−0·0535	−0·0548	−0·0508	−0·0420	−0·0292	−0·0140
5	+0·0024	+0·0181	+0·0319	+0·0422	+0·0483	+0·0496	+0·0461	+0·0382	+0·0267	+0·0129	−0·0020	−0·0163	−0·0289	−0·0384	−0·0440	−0·0453	−0·0422	−0·0350	−0·0246	−0·0119
6	+0·0016	+0·0149	+0·0264	+0·0352	+0·0405	+0·0417	+0·0389	+0·0323	+0·0228	+0·0111	−0·0014	−0·0136	−0·0243	−0·0325	−0·0374	−0·0386	−0·0361	−0·0301	−0·0212	−0·0104
7	+0·0012	+0·0126	+0·0225	+0·0302	+0·0348	+0·0360	+0·0336	+0·0281	+0·0198	+0·0098	−0·0011	−0·0117	−0·0210	−0·0282	−0·0325	−0·0337	−0·0315	−0·0263	−0·0186	−0·0092
8	+0·0009	+0·0109	+0·0197	+0·0264	+0·0305	+0·0316	+0·0296	+0·0248	+0·0176	+0·0088	−0·0008	−0·0102	−0·0185	−0·0249	−0·0288	−0·0298	−0·0280	−0·0234	−0·0166	−0·0083
9	+0·0007	+0·0096	+0·0174	+0·0235	+0·0272	+0·0282	+0·0265	+0·0222	+0·0158	+0·0079	−0·0007	−0·0091	−0·0165	−0·0223	−0·0258	−0·0268	−0·0251	−0·0211	−0·0150	−0·0075
10	+0·0006	+0·0086	+0·0157	+0·0211	+0·0245	+0·0255	+0·0239	+0·0201	+0·0143	+0·0072	−0·0005	−0·0082	−0·0149	−0·0201	−0·0234	−0·0243	−0·0228	−0·0192	−0·0137	−0·0069
11	+0·0005	+0·0078	+0·0142	+0·0192	+0·0223	+0·0232	+0·0218	+0·0183	+0·0131	+0·0066	−0·0004	−0·0074	−0·0136	−0·0184	−0·0213	−0·0222	−0·0209	−0·0176	−0·0126	−0·0064
12	+0·0004	+0·0071	+0·0130	+0·0176	+0·0205	+0·0213	+0·0201	+0·0169	+0·0121	+0·0061	−0·0004	−0·0068	−0·0125	−0·0169	−0·0197	−0·0205	−0·0193	−0·0162	−0·0116	−0·0059
13	+0·0004	+0·0065	+0·0120	+0·0163	+0·0189	+0·0197	+0·0186	+0·0156	+0·0112	+0·0057	−0·0003	−0·0063	−0·0115	−0·0157	−0·0182	−0·0190	−0·0179	−0·0151	−0·0108	−0·0055
14	+0·0003	+0·0060	+0·0111	+0·0151	+0·0176	+0·0183	+0·0173	+0·0145	+0·0104	+0·0053	−0·0003	−0·0058	−0·0107	−0·0146	−0·0170	−0·0177	−0·0167	−0·0141	−0·0101	−0·0051
15	+0·0003	+0·0056	+0·0104	+0·0141	+0·0164	+0·0171	+0·0161	+0·0136	+0·0098	+0·0050	−0·0002	−0·0054	−0·0100	−0·0136	−0·0159	−0·0166	−0·0156	−0·0132	−0·0095	−0·0048
16	+0·0002	+0·0052	+0·0097	+0·0132	+0·0154	+0·0161	+0·0152	+0·0128	+0·0092	+0·0047	−0·0002	−0·0051	−0·0094	−0·0128	−0·0149	−0·0156	−0·0147	−0·0124	−0·0089	−0·0046
17	+0·0002	+0·0049	+0·0091	+0·0124	+0·0145	+0·0151	+0·0143	+0·0121	+0·0087	+0·0044	−0·0002	−0·0048	−0·0089	−0·0121	−0·0141	−0·0147	−0·0139	−0·0117	−0·0084	−0·0043
18	+0·0002	+0·0046	+0·0086	+0·0117	+0·0137	+0·0143	+0·0135	+0·0114	+0·0082	+0·0042	−0·0002	−0·0045	−0·0084	−0·0114	−0·0133	−0·0139	−0·0132	−0·0111	−0·0080	−0·0041
19	+0·0002	+0·0044	+0·0082	+0·0111	+0·0130	+0·0136	+0·0128	+0·0108	+0·0078	+0·0040	−0·0002	−0·0043	−0·0080	−0·0108	−0·0127	−0·0132	−0·0125	−0·0106	−0·0076	−0·0039
20	+0·0001	+0·0042	+0·0078	+0·0106	+0·0123	+0·0129	+0·0122	+0·0103	+0·0074	+0·0038	−0·0001	−0·0041	−0·0076	−0·0103	−0·0120	−0·0126	−0·0119	−0·0101	−0·0072	−0·0037
21	+0·0001	+0·0040	+0·0074	+0·0101	+0·0118	+0·0123	+0·0116	+0·0098	+0·0071	+0·0036	−0·0001	−0·0039	−0·0072	−0·0098	−0·0115	−0·0120	−0·0114	−0·0096	−0·0069	−0·0036
22	+0·0001	+0·0038	+0·0070	+0·0096	+0·0112	+0·0117	+0·0111	+0·0094	+0·0068	+0·0035	−0·0001	−0·0037	−0·0069	−0·0094	−0·0110	−0·0115	−0·0109	−0·0092	−0·0066	−0·0034
23	+0·0001	+0·0036	+0·0067	+0·0092	+0·0107	+0·0112	+0·0106	+0·0090	+0·0065	+0·0033	−0·0001	−0·0035	−0·0066	−0·0090	−0·0105	−0·0110	−0·0104	−0·0088	−0·0063	−0·0033
24	+0·0001	+0·0035	+0·0065	+0·0088	+0·0103	+0·0108	+0·0102	+0·0086	+0·0062	+0·0032	−0·0001	−0·0034	−0·0063	−0·0086	−0·0101	−0·0105	−0·0100	−0·0084	−0·0061	−0·0031
25	+0·0001	+0·0033	+0·0062	+0·0085	+0·0099	+0·0103	+0·0098	+0·0083	+0·0060	+0·0031	−0·0001	−0·0032	−0·0061	−0·0083	−0·0097	−0·0101	−0·0096	−0·0081	−0·0059	−0·0030
26	+0·0001	+0·0032	+0·0060	+0·0081	+0·0095	+0·0099	+0·0094	+0·0080	+0·0057	+0·0030	−0·0001	−0·0031	−0·0058	−0·0080	−0·0093	−0·0098	−0·0092	−0·0078	−0·0056	−0·0029
27	+0·0001	+0·0031	+0·0057	+0·0078	+0·0092	+0·0096	+0·0091	+0·0077	+0·0055	+0·0029	−0·0001	−0·0030	−0·0056	−0·0077	−0·0090	−0·0094	−0·0089	−0·0075	−0·0054	−0·0028
28	+0·0001	+0·0029	+0·0055	+0·0075	+0·0068	+0·0092	+0·0088	+0·0074	+0·0053	+0·0028	−0·0001	−0·0029	−0·0054	−0·0074	−0·0087	−0·0091	−0·0086	−0·0073	−0·0053	−0·0027
29	+0·0001	+0·0028	+0·0053	+0·0073	+0·0085	+0·0089	+0·0085	+0·0072	+0·0052	+0·0027	−0·0001	−0·0028	−0·0052	−0·0072	−0·0084	−0·0088	−0·0083	−0·0070	−0·0051	−0·0026
30	+0·0001	+0·0027	+0·0052	+0·0070	+0·0082	+0·0086	+0·0082	+0·0069	+0·0050	+0·0026	−0·0001	−0·0027	−0·0051	−0·0069	−0·0081	−0·0085	−0·0080	−0·0068	−0·0049	−0·0025
31	+0·0001	+0·0027	+0·0050	+0·0068	+0·0080	+0·0084	+0·0079	+0·0067	+0·0048	+0·0025	−0·0001	−0·0026	−0·0049	−0·0067	−0·0079	−0·0082	−0·0078	−0·0066	−0·0048	−0·0025
32	+0·0001	+0·0026	+0·0048	+0·0066	+0·0077	+0·0081	+0·0077	+0·0065	+0·0047	+0·0024	−0·0001	−0·0025	−0·0048	−0·0065	−0·0076	−0·0080	−0·0076	−0·0064	−0·0046	−0·0024

AERIAL GAIN PER TIER

λ/2 DIPOLE TURNSTILES

P = 0·8806 Q = 0·3598 G = 0·4463

INTER-TIER SPACING	NUMBER OF TIERS 2	3	4	5	6	8
0·25	0·2866	0·2742	0·2957	0·3057	0·2988	0·3002
0·3	0·3189	0·3383	0·3635	0·3551	0·3521	0·3608
0·35	0·3604	0·4092	0·4144	0·4051	0·4173	0·4147
0·4	0·4117	0·4732	0·4566	0·4682	0·4737	0·4778
0·45	0·4725	0·5203	0·5068	0·5298	0·5219	0·5302
0·5	0·5394	0·5532	0·5695	0·5754	0·5817	0·5883
0·55	0·6046	0·5843	0·6305	0·6195	0·6400	0·6449
0·6	0·6563	0·6259	0·6713	0·6785	0·6810	0·6928
0·65	0·6823	0·6822	0·6961	0·7350	0·7303	0·7527
0·7	0·6771	0·7435	0·7290	0·7627	0·7893	0·7919
0·75	0·6453	0·7805	0·7842	0·7828	0·8148	0·8411
0·8	0·5977	0·7593	0·8330	0·8324	0·8301	0·8805
0·85	0·5458	0·6786	0·8003	0·8683	0·8833	0·8797
0·9	0·4972	0·5743	0·6661	0·7598	0·8401	0·9216
0·95	0·4558	0·4809	0·5143	0·5536	0·5976	0·6946
1·0	0·4229	0·4119	0·4054	0·4011	0·3980	0·3937
1·05	0·3984	0·3672	0·3438	0·3254	0·3105	0·2887
1·1	0·3817	0·3427	0·3175	0·3015	0·2918	0·2841
1·15	0·3721	0·3344	0·3162	0·3092	0·3079	0·3079
1·2	0·3690	0·3392	0·3315	0·3321	0·3323	0·3273
1·25	0·3719	0·3541	0·3554	0·3559	0·3523	0·3501
1·3	0·3805	0·3760	0·3795	0·3754	0·3729	0·3733
1·35	0·3942	0·4006	0·3998	0·3954	0·3971	0·3951
1·4	0·4124	0·4240	0·4180	0·4190	0·4195	0·4191
1·45	0·4342	0·4437	0·4383	0·4424	0·4399	0·4408
1·5	0·4580	0·4600	0·4617	0·4624	0·4630	0·4637
1·55	0·4817	0·4757	0·4848	0·4819	0·4858	0·4863
1·6	0·5024	0·4938	0·5037	0·5046	0·5050	0·5070
1·65	0·5173	0·5156	0·5189	0·5269	0·5257	0·5301
1·7	0·5243	0·5386	0·5355	0·5431	0·5484	0·5490
1·75	0·5225	0·5563	0·5571	0·5572	0·5643	0·5697

INTER-TIER SPACING	NUMBER OF TIERS 8	10	12	16	20	24	32
0·7	0·7919	0·8074	0·8158	0·8253	0·8295	0·8326	0·8384
0·72	0·8076	0·8307	0·8317	0·8444	0·8518	0·8563	0·8610
0·74	0·8288	0·8473	0·8515	0·8636	0·8711	0·8762	0·8827
0·76	0·8532	0·8582	0·8756	0·8875	0·8947	0·8997	0·9059
0·78	0·8728	0·8725	0·8934	0·9045	0·9121	0·9180	0·9268
0·8	0·8805	0·8950	0·9022	0·9194	0·9328	0·9410	0·9475
0·82	0·8780	0·9165	0·9155	0·9426	0·9522	0·9567	0·9696
0·84	0·8763	0·9221	0·9387	0·9556	0·9643	0·9786	0·9869
0·86	0·8869	0·9124	0·9515	0·9603	0·9864	0·9898	1·0055
0·88	0·9096	0·9089	0·9388	0·9810	0·9894	1·0091	1·0239
0·9	0·9216	0·9266	0·9280	0·9836	1·0014	1·0109	1·0311
0·92	0·8810	0·9386	0·9456	0·9542	1·0036	1·0226	1·0425
0·94	0·7679	0·8696	0·9341	0·9627	0·9647	0·9973	1·0429
0·96	0·6200	0·6993	0·7792	0·9094	0·9699	0·9788	0·9901
0·98	0·4884	0·5182	0·5513	0·6255	0·7066	0·7881	0·9207
1·0	0·3937	0·3910	0·3890	0·3865	0·3848	0·3836	0·3821
1·02	0·3333	0·3161	0·3052	0·2849	0·2701	0·2596	0·2476
1·04	0·2987	0·2827	0·2713	0·2584	0·2538	0·2529	0·2518
1·06	0·2826	0·2713	0·2657	0·2632	0·2626	0·2603	0·2574
1·08	0·2792	0·2742	0·2734	0·2722	0·2686	0·2673	0·2659
1·1	0·2841	0·2834	0·2830	0·2786	0·2772	0·2765	0·2751
1·12	0·2933	0·2930	0·2903	0·2871	0·2864	0·2850	0·2840
1·14	0·3033	0·3008	0·2976	0·2968	0·2949	0·2946	0·2935
1·16	0·3121	0·3080	0·3067	0·3053	0·3046	0·3036	0·3029
1·18	0·3198	0·3164	0·3165	0·3144	0·3136	0·3133	0·3123
1·2	0·3273	0·3262	0·3255	0·3242	0·3231	0·3225	0·3220
1·22	0·3357	0·3359	0·3341	0·3332	0·3327	0·3322	0·3315
1·24	0·3451	0·3448	0·3433	0·3424	0·3419	0·3415	0·3411
1·26	0·3550	0·3533	0·3532	0·3522	0·3516	0·3513	0·3508
1·28	0·3645	0·3624	0·3625	0·3615	0·3610	0·3606	0·3603
1·3	0·3733	0·3721	0·3714	0·3707	0·3705	0·3704	0·3699

RELATIVE MUTUAL RESISTANCE

DOUBLET TURNSTILES

P = 1·0   Q = 0·0

X\Y	.00	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75	.80	.85	.90	.95
0	+1.0000	+0.9804	+0.9227	+0.8306	+0.7099	+0.5679	+0.4134	+0.2554	+0.1032	-0.0350	-0.1520	-0.2424	-0.3028	-0.3322	-0.3315	-0.3040	-0.2542	-0.1883	-0.1131	-0.0354
1	+0.0380	+0.1014	+0.1503	+0.1816	+0.1940	+0.1879	+0.1651	+0.1288	+0.0833	+0.0331	-0.0169	-0.0621	-0.0988	-0.1244	-0.1354	-0.1353	-0.1215	-0.0971	-0.0648	-0.0281
2	+0.0095	+0.0441	+0.0734	+0.0942	+0.1051	+0.1056	+0.0960	+0.0778	+0.0529	+0.0240	-0.0061	-0.0344	-0.0583	-0.0758	-0.0854	-0.0865	-0.0793	-0.0648	-0.0446	-0.0208
3	+0.0042	+0.0280	+0.0483	+0.0634	+0.0719	+0.0733	+0.0676	+0.0555	+0.0385	+0.0183	-0.0031	-0.0235	-0.0413	-0.0545	-0.0621	-0.0635	-0.0588	-0.0486	-0.0339	-0.0163
4	+0.0024	+0.0204	+0.0360	+0.0473	+0.0546	+0.0561	+0.0521	+0.0432	+0.0303	+0.0147	-0.0019	-0.0179	-0.0319	-0.0445	-0.0488	-0.0502	-0.0467	-0.0388	-0.0273	-0.0134
5	+0.0015	+0.0160	+0.0297	+0.0393	+0.0441	+0.0454	+0.0424	+0.0353	+0.0249	+0.0123	-0.0013	-0.0145	-0.0260	-0.0349	-0.0402	-0.0415	-0.0388	-0.0323	-0.0229	-0.0114
6	+0.0011	+0.0132	+0.0238	+0.0320	+0.0369	+0.0382	+0.0357	+0.0298	+0.0212	+0.0106	-0.0009	-0.0121	-0.0220	-0.0295	-0.0341	-0.0353	-0.0331	-0.0277	-0.0197	-0.0099
7	+0.0008	+0.0112	+0.0204	+0.0274	+0.0317	+0.0329	+0.0309	+0.0259	+0.0184	+0.0092	-0.0007	-0.0104	-0.0190	-0.0256	-0.0297	-0.0308	-0.0289	-0.0242	-0.0173	-0.0087
8	+0.0006	+0.0097	+0.0178	+0.0240	+0.0279	+0.0289	+0.0272	+0.0228	+0.0163	+0.0082	-0.0005	-0.0091	-0.0167	-0.0216	-0.0262	-0.0273	-0.0256	-0.0215	-0.0154	-0.0078
9	+0.0005	+0.0086	+0.0158	+0.0214	+0.0248	+0.0258	+0.0243	+0.0204	+0.0145	+0.0074	-0.0004	-0.0081	-0.0149	-0.0202	-0.0235	-0.0245	-0.0230	-0.0194	-0.0139	-0.0070
10	+0.0004	+0.0077	+0.0142	+0.0192	+0.0224	+0.0233	+0.0219	+0.0184	+0.0132	+0.0067	-0.0003	-0.0073	-0.0135	-0.0183	-0.0213	-0.0222	-0.0209	-0.0176	-0.0126	-0.0064
11	+0.0003	+0.0070	+0.0129	+0.0175	+0.0204	+0.0212	+0.0200	+0.0168	+0.0121	+0.0062	-0.0003	-0.0067	-0.0123	-0.0167	-0.0195	-0.0203	-0.0192	-0.0161	-0.0116	-0.0059
12	+0.0003	+0.0064	+0.0118	+0.0160	+0.0187	+0.0195	+0.0184	+0.0155	+0.0111	+0.0057	-0.0002	-0.0061	-0.0113	-0.0154	-0.0179	-0.0187	-0.0177	-0.0149	-0.0107	-0.0055
13	+0.0002	+0.0059	+0.0109	+0.0148	+0.0173	+0.0180	+0.0170	+0.0143	+0.0103	+0.0053	-0.0002	-0.0056	-0.0105	-0.0143	-0.0160	-0.0174	-0.0164	-0.0138	-0.0099	-0.0051
14	+0.0002	+0.0054	+0.0101	+0.0138	+0.0160	+0.0168	+0.0158	+0.0133	+0.0096	+0.0049	-0.0002	-0.0052	-0.0098	-0.0133	-0.0155	-0.0162	-0.0153	-0.0129	-0.0093	-0.0048
15	+0.0002	+0.0051	+0.0094	+0.0128	+0.0150	+0.0157	+0.0148	+0.0125	+0.0090	+0.0046	-0.0002	-0.0047	-0.0091	-0.0124	-0.0145	-0.0152	-0.0143	-0.0121	-0.0087	-0.0045
16	+0.0001	+0.0047	+0.0088	+0.0120	+0.0141	+0.0147	+0.0139	+0.0117	+0.0084	+0.0044	-0.0001	-0.0046	-0.0086	-0.0117	-0.0136	-0.0143	-0.0135	-0.0114	-0.0082	-0.0042
17	+0.0001	+0.0045	+0.0083	+0.0113	+0.0132	+0.0138	+0.0131	+0.0111	+0.0080	+0.0041	-0.0001	-0.0043	-0.0081	-0.0110	-0.0129	-0.0134	-0.0127	-0.0107	-0.0077	-0.0040
18	+0.0001	+0.0042	+0.0078	+0.0107	+0.0125	+0.0131	+0.0124	+0.0105	+0.0075	+0.0039	-0.0001	-0.0041	-0.0076	-0.0104	-0.0122	-0.0127	-0.0120	-0.0102	-0.0073	-0.0038
19	+0.0001	+0.0040	+0.0074	+0.0101	+0.0119	+0.0124	+0.0117	+0.0099	+0.0072	+0.0037	-0.0001	-0.0039	-0.0072	-0.0099	-0.0116	-0.0121	-0.0114	-0.0097	-0.0070	-0.0036
20	+0.0001	+0.0038	+0.0071	+0.0096	+0.0113	+0.0118	+0.0112	+0.0094	+0.0068	+0.0035	-0.0001	-0.0037	-0.0069	-0.0094	-0.0110	-0.0115	-0.0109	-0.0092	-0.0066	-0.0034
21	+0.0001	+0.0036	+0.0057	+0.0092	+0.0107	+0.0112	+0.0106	+0.0090	+0.0065	+0.0034	-0.0001	-0.0035	-0.0066	-0.0090	-0.0103	-0.0110	-0.0104	-0.0088	-0.0063	-0.0033
22	+0.0001	+0.0034	+0.0064	+0.0038	+0.0103	+0.0107	+0.0102	+0.0086	+0.0062	+0.0032	-0.0001	-0.0033	-0.0063	-0.0086	-0.0100	-0.0105	-0.0099	-0.0084	-0.0061	-0.0031
23	+0.0001	+0.0033	+0.0061	+0.0084	+0.0098	+0.0103	+0.0097	+0.0082	+0.0059	+0.0031	-0.0001	-0.0032	-0.0060	-0.0082	-0.0096	-0.0101	-0.0095	-0.0081	-0.0058	-0.0030
24	+0.0001	+0.0031	+0.0059	+0.0080	+0.0094	+0.0098	+0.0093	+0.0079	+0.0057	+0.0030	-0.0001	-0.0031	-0.0058	-0.0079	-0.0092	-0.0096	-0.0091	-0.0077	-0.0056	-0.0029
25	+0.0001	+0.0030	+0.0056	+0.0077	+0.0090	+0.0095	+0.0090	+0.0076	+0.0055	+0.0028	-0.0001	-0.0029	-0.0055	-0.0076	-0.0089	-0.0093	-0.0088	-0.0074	-0.0054	-0.0028
26	+0.0001	+0.0029	+0.0054	+0.0074	+0.0087	+0.0091	+0.0086	+0.0073	+0.0053	+0.0027	-0.0001	-0.0028	-0.0053	-0.0073	-0.0085	-0.0089	-0.0085	-0.0072	-0.0052	-0.0027
27	+0.0001	+0.0028	+0.0052	+0.0071	+0.0084	+0.0088	+0.0083	+0.0070	+0.0051	+0.0026	-0.0001	-0.0027	-0.0051	-0.0070	-0.0082	-0.0086	-0.0082	-0.0069	-0.0050	-0.0026
28	+0.0000	+0.0027	+0.0050	+0.0069	+0.0081	+0.0085	+0.0080	+0.0068	+0.0049	+0.0025	-0.0000	-0.0026	-0.0049	-0.0068	-0.0079	-0.0083	-0.0079	-0.0067	-0.0048	-0.0025
29	+0.0000	+0.0026	+0.0049	+0.0067	+0.0078	+0.0082	+0.0077	+0.0066	+0.0047	+0.0025	-0.0000	-0.0025	-0.0048	-0.0065	-0.0077	-0.0080	-0.0076	-0.0064	-0.0047	-0.0024
30	+0.0000	+0.0025	+0.0047	+0.0064	+0.0075	+0.0079	+0.0075	+0.0063	+0.0046	+0.0024	-0.0000	-0.0025	-0.0046	-0.0063	-0.0074	-0.0078	-0.0074	-0.0062	-0.0045	-0.0023
31	+0.0000	+0.0024	+0.0045	+0.0062	+0.0073	+0.0076	+0.0072	+0.0061	+0.0044	+0.0023	-0.0000	-0.0024	-0.0045	-0.0061	-0.0072	-0.0075	-0.0071	-0.0060	-0.0044	-0.0023
32	+0.0000	+0.0023	+0.0044	+0.0060	+0.0071	+0.0074	+0.0070	+0.0059	+0.0043	+0.0022	-0.0000	-0.0023	-0.0043	-0.0059	-0.0070	-0.0073	-0.0069	-0.0059	-0.0042	-0.0022

AERIAL GAIN PER TIER

DOUBLET TURNSTILES

P = 1·0 Q = 0·0 G = 0·4571

INTER-TIER SPACING	NUMBER OF TIERS 2	3	4	5	6	8
0·25	0·2915	0·2760	0·2953	0·3051	0·2992	0·3002
0·3	0·3234	0·3387	0·3625	0·3556	0·3527	0·3608
0·35	0·3641	0·4083	0·4147	0·4062	0·4172	0·4152
0·4	0·4143	0·4721	0·4582	0·4685	0·4740	0·4778
0·45	0·4736	0·5206	0·5085	0·5298	0·5230	0·5309
0·5	0·5390	0·5556	0·5702	0·5766	0·5824	0·5888
0·55	0·6033	0·5882	0·6307	0·6216	0·6406	0·6456
0·6	0·6556	0·6299	0·6731	0·6799	0·6830	0·6943
0·65	0·6844	0·6851	0·7002	0·7362	0·7325	0·7537
0·7	0·6838	0·7451	0·7341	0·7663	0·7909	0·7945
0·75	0·6567	0·7834	0·7881	0·7887	0·8190	0·8438
0·8	0·6129	0·7680	0·8367	0·8376	0·8369	0·8845
0·85	0·5631	0·6947	0·8106	0·8742	0·8889	0·8878
0·9	0·5153	0·5950	0·6861	0·7768	0·8528	0·9295
0·95	0·4739	0·5025	0·5380	0·5785	0·6229	0·7189
1·0	0·4403	0·4324	0·4277	0·4246	0·4223	0·4192
1·05	0·4150	0·3860	0·3635	0·3455	0·3307	0·3088
1·1	0·3973	0·3598	0·3350	0·3190	0·3093	0·3015
1·15	0·3868	0·3499	0·3318	0·3247	0·3233	0·3232
1·2	0·3828	0·3532	0·3454	0·3457	0·3458	0·3408
1·25	0·3848	0·3667	0·3674	0·3677	0·3641	0·3618
1·3	0·3923	0·3869	0·3899	0·3858	0·3833	0·3835
1·35	0·4049	0·4100	0·4088	0·4045	0·4059	0·4038
1·4	0·4219	0·4320	0·4260	0·4266	0·4269	0·4264
1·45	0·4424	0·4506	0·4452	0·4488	0·4464	0·4470
1·5	0·4649	0·4662	0·4674	0·4678	0·4683	0·4687
1·55	0·4873	0·4814	0·4894	0·4866	0·4900	0·4903
1·6	0·5072	0·4989	0·5077	0·5083	0·5086	0·5103
1·65	0·5219	0·5197	0·5226	0·5297	0·5286	0·5324
1·7	0·5293	0·5417	0·5389	0·5457	0·5504	0·5509
1·75	0·5286	0·5591	0·5597	0·5598	0·5662	0·5710

INTER-TIER SPACING	NUMBER OF TIERS 8	10	12	16	20	24	32
0·7	0·7945	0·8090	0·8171	0·8263	0·8304	0·8334	0·8390
0·72	0·8106	0·8323	0·8336	0·8457	0·8528	0·8570	0·8616
0·74	0·8318	0·8493	0·8536	0·8652	0·8724	0·8773	0·8836
0·76	0·8558	0·8613	0·8775	0·8890	0·8960	0·9007	0·9067
0·78	0·8755	0·8762	0·8957	0·9065	0·9138	0·9195	0·9279
0·8	0·8845	0·8984	0·9057	0·9221	0·9347	0·9425	0·9488
0·82	0·8840	0·9199	0·9197	0·9451	0·9544	0·9589	0·9710
0·84	0·8840	0·9268	0·9426	0·9590	0·9675	0·9808	0·9889
0·86	0·8950	0·9197	0·9561	0·9651	0·9895	0·9931	1·0078
0·88	0·9171	0·9179	0·9463	0·9858	0·9942	1·0125	1·0266
0·9	0·9295	0·9354	0·9378	0·9900	1·0069	1·0161	1·0352
0·92	0·8935	0·9477	0·9551	0·9647	1·0107	1·0286	1·0475
0·94	0·7887	0·8854	0·9459	0·9737	0·9767	1·0072	1·0496
0·96	0·6465	0·7247	0·8021	0·9257	0·9825	0·9915	1·0031
0·98	0·5158	0·5467	0·5804	0·6550	0·7349	0·8138	0·9398
1·0	0·4192	0·4172	0·4158	0·4139	0·4126	0·4118	0·4106
1·02	0·3564	0·3411	0·3281	0·3074	0·2922	0·2813	0·2688
1·04	0·3197	0·3034	0·2918	0·2785	0·2738	0·2729	0·2717
1·06	0·3020	0·2905	0·2848	0·2822	0·2817	0·2793	0·2763
1·08	0·2975	0·2924	0·2915	0·2903	0·2867	0·2854	0·2840
1·1	0·3015	0·3007	0·3002	0·2958	0·2945	0·2937	0·2923
1·12	0·3098	0·3094	0·3068	0·3035	0·3028	0·3014	0·3003
1·14	0·3190	0·3164	0·3132	0·3124	0·3105	0·3102	0·3090
1·16	0·3270	0·3229	0·3216	0·3201	0·3194	0·3184	0·3177
1·18	0·3339	0·3306	0·3306	0·3284	0·3277	0·3273	0·3263
1·2	0·3408	0·3396	0·3389	0·3375	0·3364	0·3358	0·3353
1·22	0·3485	0·3486	0·3467	0·3458	0·3452	0·3448	0·3441
1·24	0·3572	0·3569	0·3553	0·3544	0·3538	0·3534	0·3529
1·26	0·3664	0·3647	0·3644	0·3634	0·3628	0·3624	0·3619
1·28	0·3753	0·3731	0·3731	0·3721	0·3715	0·3712	0·3708
1·3	0·3835	0·3821	0·3814	0·3807	0·3804	0·3802	0·3798

APPENDIX IV

THE GAIN PER TIER OF INFINITE ARRAYS

The limiting value of the gain per tier when the number of tiers tends to infinity is discussed in Section 2.6. For spacings less than one wavelength it is independent of the radiation pattern of the individual tiers and is equal to $1{\cdot}21883x/\lambda$ relative to a $\lambda/2$ dipole, where x is the inter-tier spacing.

For spacings greater than one wavelength the gain is a function of the parameters P and Q which define the radiation pattern of the tiers. For spacings between one and two wavelengths the gain per tier relative to a $\lambda/2$ dipole is given by

$$\frac{1{\cdot}21883\dfrac{x}{\lambda}}{3+2P\left(\dfrac{\lambda}{x}\right)^2+2Q\left(\dfrac{\lambda}{x}\right)^4}$$

Values of G/n for spacings between one and two wavelengths for the ten cases considered are tabulated below.

$\frac{x}{\lambda}$	$P=-3$ $Q=2{\cdot}25$	$P=-2$ $Q=1$	$P=-1{\cdot}4294$ $Q=0{\cdot}4294$	$P=-1$ $Q=0$	$P=0$ $Q=-1$	$P=3$ $Q=-4$	$P=-1$ $Q=0{\cdot}25$	$P=0$ $Q=0$	$P=0{\cdot}8806$ $Q=0{\cdot}3598$	$P=1$ $Q=0$
1·00	0·813	1·219	1·219	1·219	1·219	1·219	0·813	0·406	0·222	0·244
1·05	1·015	1·256	1·149	1·078	0·945	0·688	0·801	0·427	0·247	0·266
1·10	1·203	1·265	1·096	0·996	0·821	0·537	0·794	0·447	0·271	0·288
1·15	1·351	1·251	1·054	0·942	0·755	0·473	0·790	0·467	0·296	0·311
1·20	1·459	1·234	1·024	0·908	0·719	0·442	0·790	0·488	0·320	0·333
1·25	1·516	1·210	1·001	0·886	0·699	0·428	0·792	0·508	0·345	0·356
1·30	1·545	1·189	0·985	0·872	0·689	0·423	0·796	0·528	0·369	0·379
1·40	1·538	1·153	0·967	0·862	0·689	0·429	0·809	0·569	0·418	0·425
1·50	1·496	1·130	0·962	0·866	0·702	0·447	0·827	0·609	0·466	0·470
1·60	1·452	1·119	0·968	0·879	0·724	0·473	0·850	0·650	0·513	0·516
1·70	1·416	1·117	0·980	0·898	0·750	0·503	0·875	0·691	0·561	0·561
1·80	1·391	1·122	0·997	0·921	0·781	0·536	0·903	0·731	0·607	0·607
1·90	1·376	1·133	1·018	0·947	0·813	0·572	0·932	0·772	0·654	0·652
2·00	1·369	1·147	1·042	0·975	0·848	0·610	0·963	0·812	0·700	0·697

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